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Chemically Active Fluid Bed (CAFB) Process Solids Transport Studies

Foster Wheeler Energy Corp, Livingston, N J

Prepared for

Industrial Environmental Research Lab, Research Triangle Park, N C

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Office of Research and Development
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Laboratory
Research Triangle Park, North Carolina 27711

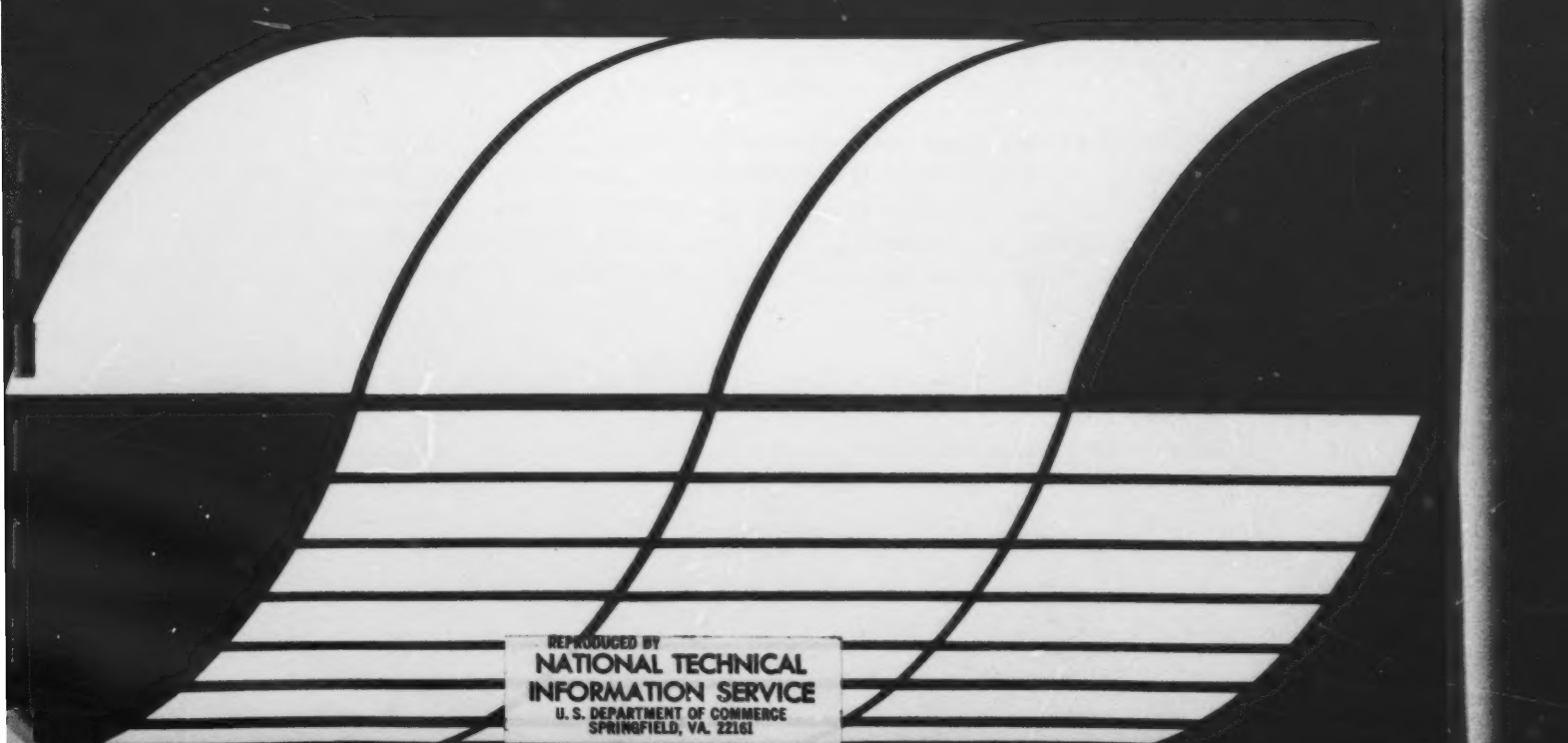
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CHEMICALLY ACTIVE FLUID BED (CAFB) PROCESS SOLIDS-TRANSPORT STUDIES

Interagency
Energy-Environment
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Program Report

A large, abstract graphic design at the bottom of the cover. It features a series of horizontal lines that are interrupted by three large, curved, overlapping shapes that resemble stylized waves or the profile of a fluid bed. The design is composed of black lines on a white background.

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16. ABSTRACT The report describes cold-modeling efforts directed toward the development of a solids-transport system capable of transferring 40,000 lb/hr of bed material between two operating fluidized beds of a chemically active fluidized bed (CAFB) gasification/desulfurization commercial demonstration unit. Three completely different configurations were tested, including at least one modification of each design. The optimum system would: transfer the required amount of bed material per unit time between the two fluidized beds; use the minimum quantity of activating gas; maintain the minimum activating gas pressure; allow only minimal gas leakage back into the supply bed; and provide an accurate and reliable control of transfer rate. A modified version of the third configuration tested (consisting of vertical and horizontal tubes with rectangular cross section and a multitube transport-gas sparger) was selected as coming closest to these specifications.

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CHEMICALLY ACTIVE FLUID BED (CAFB) PROCESS SOLIDS-TRANSPORT STUDIES

by

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FOREWORD

The Chemically Active Fluid Bed (CAFB) gasification/desulfurization process is a very promising new technique for the environmentally satisfactory use of high-sulfur residual oil and high-sulfur coal in combustion systems. To that end the design of the first commercial demonstration unit raised some uncertainties concerning process equipment configuration. One such uncertainty was the transfer of bed material to and from the gasifier and regenerator. A completely reliable solids-transfer system is absolutely essential to the basic operation of the gasifier and regenerator.

To support the design of the commercial demonstration unit, a full-scale cold-model study was initiated to determine the correct configuration of the transfer ducts. After several unsuccessful arrangements were tried, a satisfactory working model was developed. The final configuration has been included in the design of the demonstration plant.

F. D. Zoldak
CAFB Program Manager

ABSTRACT

Cold-modeling efforts directed toward the development of a solids-transport system capable of transferring 40,000 lb/h of bed material between two operating fluidized beds are described in this report. Three completely different configurations were tested, including at least one modification of each design. The optimum system, against which all the candidate systems were compared, would:

- Transfer the required amount of bed material per unit time between the two fluidized beds
- Use the minimum quantity of activating gas
- Maintain the minimum activating gas pressure
- Allow only minimal gas leakage back into the "supply" bed
- Provide an accurate and reliable control of transfer rate.

Based on these specifications, a modified version of the third configuration tested (consisting of vertical and horizontal tubes with rectangular cross section and a multi-tube transport-gas sparger) was selected as most closely approaching the optimum conditions when compared with the other systems tested.

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LIST OF SYMBOLS AND ABBREVIATIONS

<u>Symbol</u>	<u>Description</u>
A	Distance at inlet with respect to reference level
a	Least-squares regression coefficient
Ac.s.	Fluidized-bed cross-sectional area
A _F	Free area of perforated plate
Amps	Fan input amps
Area _{Bed}	Fluidized-bed cross-sectional area
Area _{Plate}	Perforated-plate cross-sectional area
B	Distance at outlet with respect to reference level
b	Least-squares regression coefficient
Bed Ht.	Bed height
Bed Wt.	Bed weight
C	Orifice coefficient
c _{pg}	Mean specific heat of gas
c _{ps}	Mean specific heat of solids
D ₁	Pipe diameter
d _h	Hole diameter
d _o	Orifice diameter
dp _a	Surface average particle size
dsv	Sieve size

LIST OF SYMBOLS AND ABBREVIATIONS (Cont)

<u>Symbol</u>	<u>Description</u>
e	Error
e_c	Individual cell composite percentage error
e_{TS}	Total system percentage error
G	Gasifier
g	Acceleration of gravity
g_c	Newton's law conversion factor
h	Bed height
J	Mechanical equivalent of heat
K	Orifice flow coefficient
K_f	Perforated-plate flow coefficient
$M, \dot{M}_{\text{Fluidizing}}$	Mass flow rate of fluidizing air
MW_{Air}	Molecular weight of air
$\dot{M}$	Mass flow rate
$\dot{M}_{\text{Bleed Air}}$	Bleed air mass flow rate
$\dot{M}_{\text{Bypass}}$	Bypass system mass flow rate
$\dot{M}_{\text{Pulse Air}}$	Pulse air mass flow rate
$\dot{M}_{\text{Total}}$	Total air flow rate
N	Number of samples
n	Number of data points
P	Absolute pressure
P_1	Orifice upstream pressure
P_{Annubar}	Annubar downstream pressure

LIST OF SYMBOLS AND ABBREVIATIONS (Cont)

<u>Symbol</u>	<u>Description</u>
$P_{\text{Control Valve}}$	Control valve signal pressure
$P_{\text{Fan Exit}}$	Fan exit pressure
P_{Plenum}	Plenum pressure
P_{Sparger}	Sparger pressure
$P_{\text{Surge Tank}}$	Surge tank pressure
P_{Tank}	Pulse-air supply pressure
P_{Top}	Pressure above bed
QL	Heat loss
R	Mass flow of solids
R	Regenerator
r^2	Linear correlation coefficient
Re_D	Reynolds number based on pipe diameter
Re_h	Reynolds number based on perforated-plate hole diameter
Rg	Universal gas constant
Sample _i	Gasifier-to-regenerator weight samples collected in 30 seconds
S_x, S_y	Standard deviation
T	Absolute temperature
T	Total
t	Time
T_o	Reference temperature
t_o, T_1	Orifice downstream temperature
T_A	Ambient temperature

LIST OF SYMBOLS AND ABBREVIATIONS (Cont)

<u>Symbol</u>	<u>Description</u>
$\left. \begin{matrix} t_{\text{Annubar}} \\ T_{\text{Annubar}} \end{matrix} \right\}$	Annubar downstream temperature
$\left. \begin{matrix} t_{\text{Fan Exit}} \\ T_{\text{Fan Exit}} \end{matrix} \right\}$	Fan exit temperature
$\left. \begin{matrix} t_{\text{Plenum}} \\ T_{\text{Plenum}} \end{matrix} \right\}$	Plenum temperature
$t_{\text{Tank}}, T_{\text{Tank}}$	Pulse-air supply temperature
U	Gas superficial velocity
UA	Heat-transfer constant for external walls
V_{Plenum}	Plenum chamber approach velocity
V_{Tank}	Internal volume of pulse-air supply tank
V_x, V_y	Coefficients of variation
W	Bed weight
Wt./30 s	Gasifier-to-regenerator weight samples collected in 30 seconds
$\dot{W}_{\text{Bypass}}$	Bypass system mass flow rate
X	Individual load-cell capacity
$\bar{x}$	Average value
X_i	Percent by weight
x_i	Data point, independent variable
X_T	Total system load-cell capacity
Y	Expansion factor
y_i	Data point, dependent variable
Z	Distance above reference level
α_{xy}	Correlation coefficient

LIST OF SYMBOLS AND ABBREVIATIONS (Cont)

<u>Symbol</u>	<u>Description</u>
β	Orifice-to-pipe diameter ratio
β_I	Individual cell composite absolute error
β_{TS}	Total system absolute error
ΔH	Change in enthalpy
ΔKE	Change in kinetic energy
$\dot{M}_{\text{Total Air}}$	Pulse-air supply total air usage
$\Delta P_{\text{Annubar}}$	Annubar differential pressure
$\Delta P_{\text{Bed-12}}$	Bed differential pressure (12 in.)
$\Delta P_{\text{Bed-24}}$	Bed differential pressure (24 in.)
$\Delta P_{\text{Bed-100}}$	Bed differential pressure (100 in.)
ΔPE	Change in potential energy
$\Delta P(\text{Plate})$	Perforated-plate pressure differential
ΔP_o	Orifice differential pressure
ΔP_{Tank}	Pulse-air supply pressure difference
ΔW	Change in weight
μ	Viscosity
ρ_{Bed}	Bed-material bulk density
$\rho_{\text{Bleed Air}}$	Bleed air gas density
ρ_g	Gas density
ρ_{Plenum}	Plenum chamber gas density
ρ_{Top}	Gas density above fluidized bed
σ^2	Variance
σ_T	Composite load-cell error

LIST OF SYMBOLS AND ABBREVIATIONS (Cont)

<u>Symbol</u>	<u>Description</u>
θ_{Op}	Operating time
$\theta_{Pulse\ 1}$	Pulse to regenerator - On time
$\theta_{Pulse\ 2}$	Pulse to regenerator - Off time
$\theta_{Pulse\ 3}$	Pulse to gasifier - On time
$\theta_{Pulse\ 4}$	Pulse to gasifier - Off time

CONVERSION FACTORS--ENGLISH TO SI UNITS

Quantity	English System		SI Equivalent	
	Unit Symbol	Unit Name	Unit Symbol	Unit Name
Length	in.	inch	$2.540 \times 10^{-2} \text{ m}$	meter
	ft	foot	$3.048 \times 10^{-1} \text{ m}$	meter
Area	in^2	square inch	$6.452 \times 10^{-4} \text{ m}^2$	square meter
	ft^2	square foot	$9.290 \times 10^{-2} \text{ m}^2$	square meter
Volume	ft^3	cubic foot	$2.832 \times 10^{-2} \text{ m}^3$	cubic meter
	gal	U.S. gallon	$3.785 \times 10^{-3} \text{ m}^3$	cubic meter
Velocity	ft/s	foot per second	$3.048 \times 10^{-1} \text{ m/s}$	meter per second
Mass	lb	pound (avoird)	$4.536 \times 10^{-1} \text{ kg}$	kilogram
	t	ton (short)	$9.072 \times 10^2 \text{ kg}$	kilogram
Pressure	lb/in^2	pound per square inch	$6.895 \times 10^3 \text{ Pa}$	pascal
	in. H ₂ O	inch of water (can also be differential)	$2.488 \times 10^2 \text{ Pa}$	pascal
Temperature	°F	degree Fahrenheit	$(°\text{F}-32)/1.8 = °\text{C}$	degree Celsius
	°R	degree Rankine	°R/1.8 = K	kelvin
Energy	Btu	British thermal unit	$1.055 \times 10^3 \text{ J}$	joule
	Btu/h	British thermal unit per hour	$2.931 \times 10^{-1} \text{ W}$	watt
Flow Rate	lb/h	pound per hour	$1.260 \times 10^{-4} \text{ kg/s}$	kilogram per second
	ft^3/min	cubic foot per minute	$4.720 \times 10^{-4} \text{ m}^3/\text{s}$	cubic meter per second

Prefix Definitions

a	actual*
s	standard
k	kilo

Suffix Definitions

a	absolute†
g	gage

*When dealing with volumetric flow rate.

†When dealing with pressure.

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Section 1

INTRODUCTION

Foster Wheeler Energy Corporation (FWEC) is under contract with the U.S. Environmental Protection Agency (EPA) and Central Power and Light Company (CPL) of Corpus Christi, Texas, for the design, construction, and testing of a 17.5-MW Chemically Active Fluid Bed (CAFB) Process Demonstration Plant retrofitted to a 20-MW natural-gas-fired steam generator at the La Palma Station in San Benito, Texas. The objective of the CAFB process is to produce a low-sulfur fuel gas suitable for power-plant utilization in a conventional steam generator.

In the CAFB gasifier, high-sulfur fuel (liquid or solid) is injected into a 1600°F* bed of lime (in situ calcined limestone) that is fluidized by a mixture of flue gas and sub-stoichiometric air (≈22 percent of stoichiometric). The sulfur in the fuel is oxidized to a variety of sulfur compounds that are predominantly reduced to hydrogen sulfide (H_2S). The H_2S formed reacts with the lime to form calcium sulfide (CaS).

The CAFB gasification process is limited, however, by a decreasing ability of the lime to absorb sulfur as the concentration of sulfur on the bed material increases. To maintain the sulfur removal efficiency (SRE) of the CAFB gasifier, the sulfur-laden bed material must be removed from the gasification zone and replaced with sulfur-free lime. Two methods of sulfur-free lime replacement are available: (1) removal of spent stone and replacement with fresh limestone or (2) regeneration of the spent stone in a regeneration vessel with recirculation to the gasifier vessel for further sulfur absorption. Based on the desirability of limiting the amount of sorbent required, and consequently the amount of spent sorbent that must be removed, the regeneration mode of operation was chosen for the demonstration plant.

Continuous pilot-plant tests conducted by Esso Research Centre, Abingdon (ERCA), United Kingdom, have demonstrated that optimum regeneration of CaS to calcium oxide (CaO) occurs at a temperature of ≈1900°F. Since the predominant reactions occurring within the regenerator are all highly exothermic, a method of cooling the regenerator to maintain this optimum operating temperature was required. The method utilized in the ERCA pilot plant involved the circulation

*Metric conversions appear in the conversion factor table on p. xxiii.

of large quantities of bed material between the 1900°F regenerator and the 1600°F gasifier. By circulating bed material between gasifier and regenerator vessels not only is the required amount of sulfur-laden stone regenerated and recirculated to the gasification zone, but the optimum regenerator temperature is maintained by the transfer of heat from the regenerator to the gasifier. The heat transferred to the gasifier is removed through absorption in the gasifier recycle flue gas stream.

Operation of the CAFB process is highly dependent on the efficient and reliable operation of the bed-material transfer system. A pulsed-jet transfer system was used in the ERCA pilot plant, and a similar system was envisioned for use in the La Palma demonstration plant. The maximum material transfer rate obtainable in the ERCA pilot plant was ≈1000 lb/h, while the rates required at the demonstration plant are between 20,000 and 30,000 lb/h. Since a very large scale-up factor was involved, and ERCA had stated that full-scale cold modeling of the pilot plant system had proved useful, it was decided that the proposed demonstration-plant bed-material transfer system would be modeled at full-scale using an existing 36-ft² (cross-sectional plan area) cold model located at FWEC.

Section 2

TEST MODEL AND TEST LOOP

2.1 TEST MODEL

The 36-ft² cold model, which was used to study fluidized-bed characteristics as related to the development of the multicell fluidized-bed steam generator under ERDA Contract E(49-18)-1237, appears in Figure 2.1. The model consists of a steel chamber, 6 ft on a side and 11 ft high, with Plexiglas windows so positioned as to allow visual observation of the fluidized bed. As originally designed, a single 2-ft-deep bed of material rested on a removable multi-sectioned perforated-plate air distributor. The lower 2-ft-high section of the model below the air-distributor plate was used as a plenum chamber. The model is supported 4 ft above floor level to allow access to the plenum chamber.

2.2 TEST LOOP

A schematic of the test loop required to complete the fluidized-bed steam generator testing program appears in Figure 2.2. For the CAFB bed-material transfer system testing, neither the coal nor fly-ash injection systems were used and the tube bundle was removed. Air is supplied to the model by two high-pressure centrifugal blowers. Flow rate for each blower can be controlled by individual control dampers in each blower outlet duct. The air next passes into the plenum chamber, where its temperature and pressure are measured; through the air-distributor plate and bed; and into a cyclone separator and is exhausted through an exit duct from the laboratory. Elutriated bed material is collected in a bin beneath the cyclone dust-collector exit.

The external bed-material removal and recycle systems are also illustrated in Figure 2.2. Bed material issues from a pipe located in a side wall of the model onto a vibrating table feeder that discharges into the hopper feed section of a bucket elevator. The bucket elevator discharges into a 4-in. pipe that angles down across the space above the bed. This pipe discharges in the far corner of the model, diagonally opposite the bed removal point.

Since the fluidizing-air flow rate required by the CAFB cold-model testing was significantly lower than that required by the previous testing, a bypass-air system was installed in the blower outlet ducts. Orifice plates

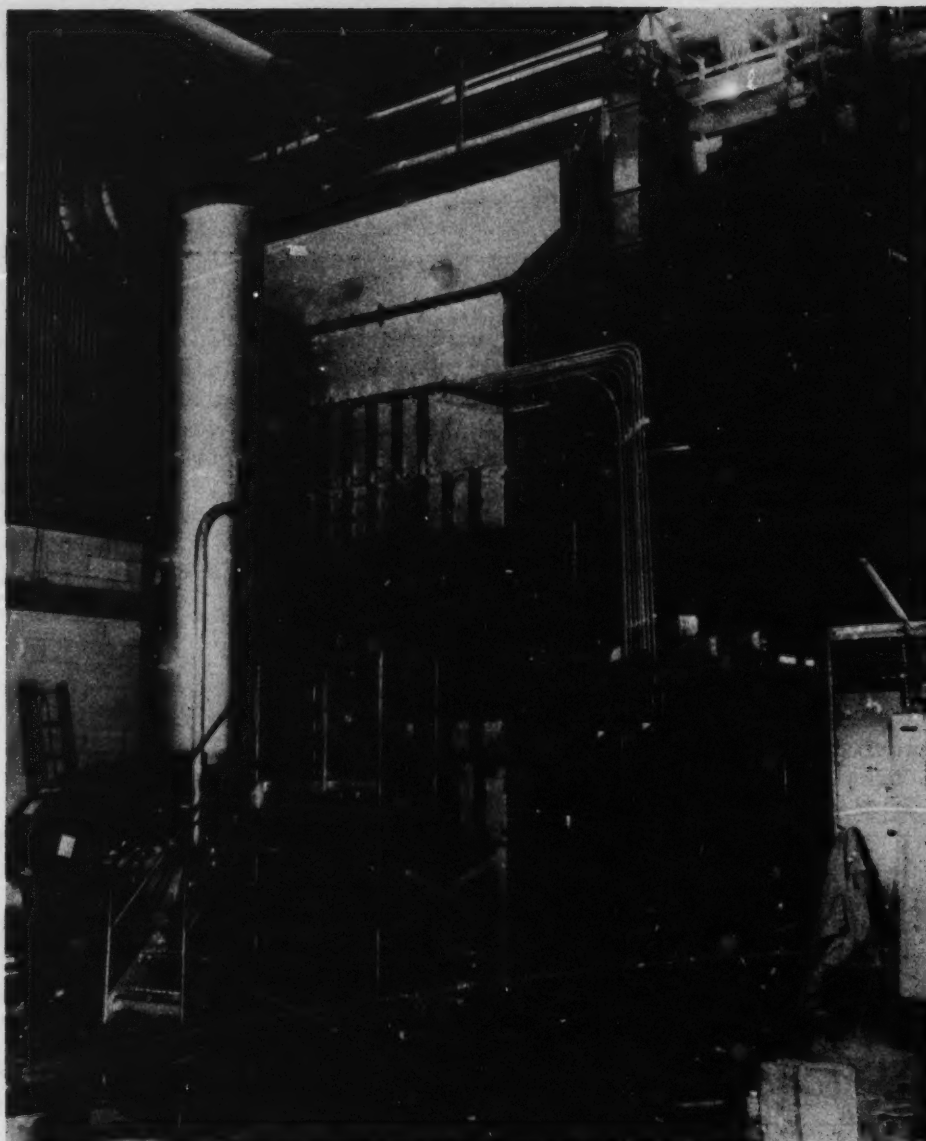


Figure 2.1 Photograph of 36-ft² Cold Model

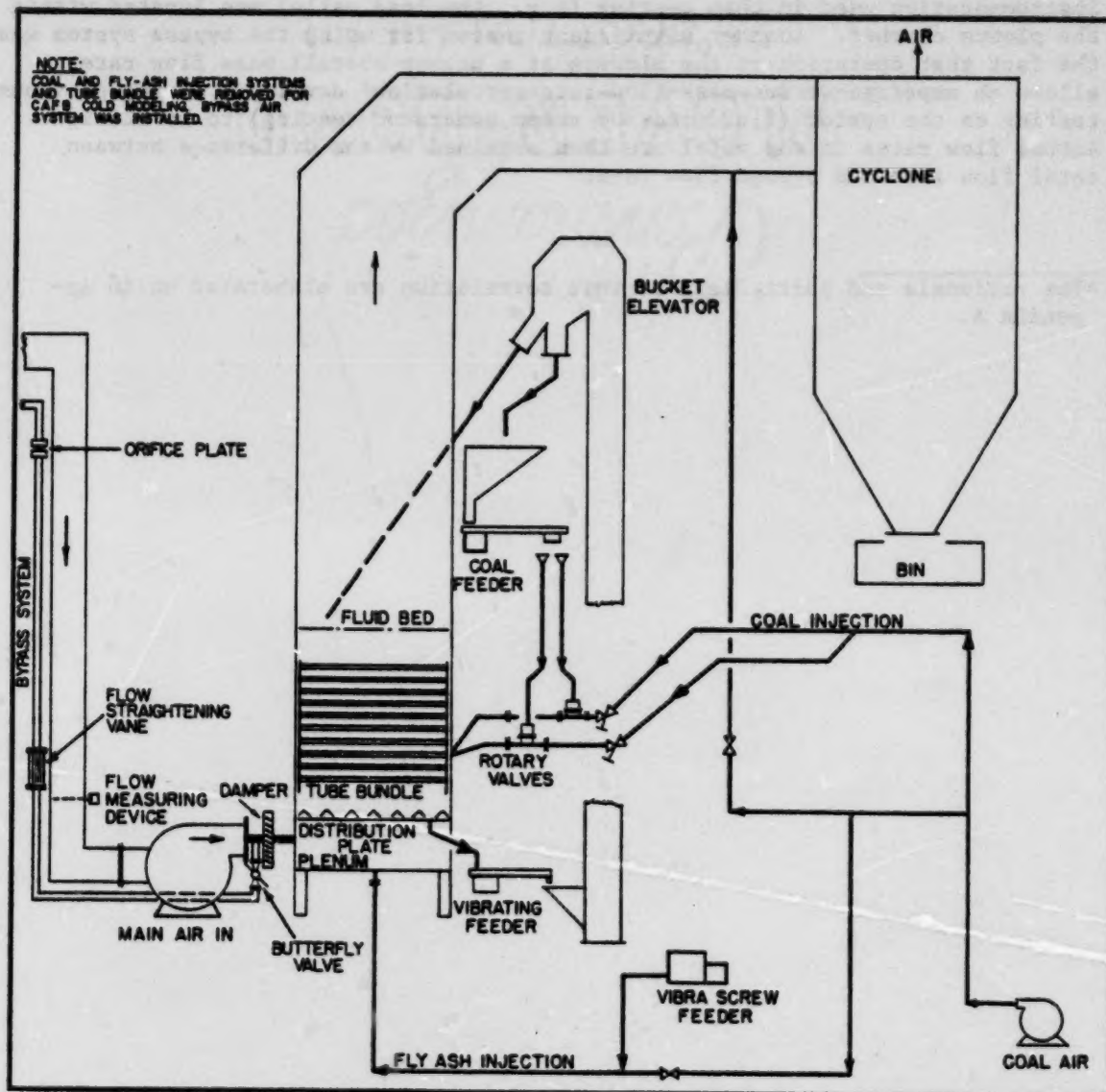


Figure 2.2 Test Loop Schematic for 36-ft² Cold-Model System

were used to measure the bypass-air flow rate. In addition to an improvement in flow-rate control, the bypass-air system allows for system operation at a lower plenum temperature than could be obtained by operating the blowers at a lower point on the blower operating curve. Operation at a lower plenum temperature is important in the CAFB testing because certain temperature-sensitive instrumentation used in this testing (e.g., the load cells) was located within the plenum chamber. Another significant reason for using the bypass system was the fact that operation of the blowers at a higher overall mass flow rate allows an amperage-versus-mass-flow-rate correlation* developed during previous testing on the system (fluidized-bed steam generator testing) to be utilized. Actual flow rates to the model are then obtained by the difference between total flow rate and bypass flow rate.

*The rationale and particulars of this correlation are elaborated on in Appendix A.

directed to the design of the system required to generate, control, and measure the air pulse. The air pulse generating bed material is and from the gasifier and regenerator. The original air supply considered was an available pressure blower. The air pulse was to be generated by a blower. A more detailed examination of the use of solenoid valves controlled by air. A more detailed examination of this system, however, revealed two serious deficiencies. First, to maintain a 2- to 3-lb/in² pressure at the transfer point, the piping system from the blower to the transfer duct would have to be approximately 1/2 in. in diameter. The solenoid valves that produce this pressure would be expensive and slow-acting. Second, measurement of the quantity of air used to transfer material (e.g., orifices) are slow to respond to the rapid changes in back pressure as the solenoid cycle on and off.

Section 3

GASIFIER-REGENERATOR BED-MATERIAL TRANSFER SYSTEM DEVELOPMENT

3.1. PRELIMINARY DESIGN CONSIDERATIONS

3.1.1. Information From ERCA

Design work on the bed-material transfer system began with a review of ERCA's cold-model work^{1*} on the pilot-plant bed-material transfer system. This review provided sufficient background so that questions concerning ERCA's previous modeling experience (and how this experience could be applied to the new modeling work) could be discussed during meetings between ERCA and FWEC personnel in Abingdon in August 1975.² At this meeting, ERCA elaborated on the cold-modeling information presented in their published reports, supplied FWEC with several typical values for operating variables, and reviewed with FWEC a preliminary design that had been developed by FWEC based on ERCA's published data.

3.1.2. Gasifier-Regenerator Bed-Material Transfer Measurement System

During the Abingdon visit, consideration was also given to the method that would be used to measure material flow between gasifier and regenerator. ERCA proposed that the method used in the continuous pilot-plant cold-model tests be used. This method utilized an analogy between heat transfer and mass transfer to obtain mass flow rates from temperature measurements. FWEC was in favor of a system that replaced the gasifier and regenerator air-distributor plates with perforated-plate weighbridges using strain-gage load beams to measure the change in weight when bed material was transferred between gasifier and regenerator. A comparison performed by FWEC of the accuracy and cost of each system showed the load-beam system to be superior in both respects. Consequently, the load-beam system was used in the FWEC cold-model work. The comparison used to make this decision is presented in Appendix B.

3.1.3. Air-Pulse System Generation--Measurement and Control

While the preliminary design that had been reviewed by ERCA and FWEC at Abingdon was being incorporated within the 36-ft² cold model, attention was

*Numbers designate references listed in Section 7.

directed to the design of the system required to generate, control, and measure the air pulses transferring bed material to and from the gasifier and regenerator. The original air supply considered was an available pressure blower operating at a pressure of 4 lb/in²g. Air pulses would be generated by the use of solenoid valves controlled by timers. A more detailed examination of this system, however, revealed two serious deficiencies. First, to maintain a 2- to 3-lb/in²g pressure at the transfer duct, the piping system from the blower to the transfer duct would have to be approximately 4 in. in diameter. The solenoid valves that produce the pulsating flow would become expensive and slow-acting. Second, measurement of the quantity of air used to transfer material is inherently inaccurate, because the usual flow-measurement devices (e.g., orifices) are slow to respond to the rapid changes in back pressure as the solenoids cycle on and off.

An alternate air supply that would give an accurate indication of the air used to transfer bed material and would allow the use of 2-in.-diameter pipelines (with correspondingly smaller, faster-acting solenoid valves) involved the use of a large pressure vessel available at the Foster Wheeler John Blizard Research Center in Livingston. The vessel would be pressurized to 100 lb/in²g using plant air, which is subsequently introduced into the gasifier or regenerator through the solenoid valves previously mentioned. The amount of air used during a test would be calculated from the change in tank pressure, in a manner analogous to that used for small gas cylinders. Since this latter design avoided the two major deficiencies in the original system, it was incorporated as part of the overall test system.

3.1.4 Cold-Model Bed-Material Selection

In preparation for preliminary system testing, a survey was performed by FWEC to obtain a suitable bed material for use in the cold model. Based on ERCA's cold-modeling experience, the bed material used was required to have a size distribution between 630 and 3200 μ m and a bulk density of 81 lb/ft³. This last specification proved to be the most troublesome. The sand used in previous cold-modeling work at FWEC was not suitable, because its bulk density was closer to 100 lb/ft³. A literature search indicated that few materials have a bulk density around 80 lb/ft³, but among the few listed were high-clay-content brick, certain slags, and certain limestones.

Crushed brick had been used by ERCA, so inquiries were made to brick suppliers in the New Jersey area. Two obstacles were encountered: (1) the bricks in the area are not high in clay and do not have the proper bulk density, and (2) obtaining brick in crushed form was not possible, and FWEC would have to crush and size the material.

The next material considered was a basic oxygen furnace slag that had been used at FWEC as a fluidized-bed material in an 18-in.-diameter atmospheric fluidized-bed combustor. Several laboratory tests indicated that this material had the correct bulk density and that after it was sieved and blended could serve as an acceptable bed material in the cold-modeling work. Problems arose, however, with respect to materials handling. The slag is an outdoor

material containing considerable surface moisture, is delivered in bulk only, and is always partially frozen in the winter. To be usable, this material would have to be shoveled into drums, sent out to be dried (FWEC does not have sufficient drying facilities), redelivered in a dry condition in drums, and sieved and blended. The cost of all these operations was estimated at approximately \$2,000. The cost of drying alone was quoted at \$75/h excluding shipping, drums, etc. In addition, twice as much material as required for the bed weights would have to be processed, since approximately 50 percent of the material is lost during the sieving operation. The time involved in performing these operations would also have caused an unacceptable delay in the cold-modeling program.

The last material explored was limestone. Most limestones are unacceptable since their bulk densities are close to 100 lb/ft³. One limestone was found, however, with a loose bulk density of 89 lb/ft³. A size analysis for this limestone appears in Table 3.1. A table of size distributions is presented in Table 3.2. These size analyses include:

- Fresh and aged crushed brick used in the ERCA cold-model work³
- Several gasifier bed samples from ERCA's continuous pilot plant in Abingdon, Runs 6 and 7
- Candidate materials for the FWEC cold-model work.⁴

Although there are variances, the limestone size distribution compares favorably with the ERCA data. The limestone was delivered in bags (which eliminated a major solids-handling problem), was readily available, could be used in the as-received form (no sieving required), and cost only \$300 delivered. Although the bulk density was higher than desired, based on the foregoing reviews, the limestone material was ordered for use as bed material within the cold model.

3.2 PRIMARY GASIFIER-REGENERATOR BED-MATERIAL TRANSFER SYSTEM

3.2.1 Primary Gasifier-Regenerator Bed-Material Transfer System-- Original Configuration

The original bed-material transfer slot geometry and sparger design appear in Figures 3.1 and 3.2. The transfer slots installed in the cold model reproduced, full-scale, the transfer-slot design envisioned for installation at La Palma. The transfer-slot dimensions were developed as a result of consultations with ERCA in August 1975. Two dimensions, especially, were developed directly from these discussions. First, the horizontal slot discharges were set 6 in. above the air-distributor plate; second, the length of the horizontal section of the bed-material transfer slot was set at ≈24 in. (see Figure 3.1). ERCA indicated that the "hot" angle of repose (angle made by pile of material with the horizontal) of the material was approximately 15 degrees, and the long length of the horizontal section is, therefore, necessary to prevent "freewheeling" of the material from the slot. (Freewheeling refers to the movement of material from the slot without any pulsed air used as a driving force.) A close-up of the transfer slot illustrating the 15-degree angle of repose appears in Figure 3.3.

Table 3.1 FWEC Limestone Bed-Material Size Analysis

Material: Limestone (Franklin 8-26 mesh)
Average Particle Size*: 750 μm

Bulk Density: 89 lb/ft^3
Particle Density: 262 lb/ft^3

Sieve Number (square)	Sieve Size (μm)	On (%)	Through (%)
12	1700	0.1	99.9
14	1400	0.3	99.6
16	1190	8.3	91.3
18	1000	22.6	68.7
20	850	15.7	53.0
25	710	33.0	20.0
30	595	10.7	9.3
50	297	6.5	2.8
100	149	0.9	1.9
140	105	0.4	1.5
200	74	0.2	1.3
325	44	0.3	1.0

$$\text{*Average Particle Size} = dp_a = \frac{1}{\sum_{i=1}^n \left(\frac{x_i}{dp_i} \right)}$$

where

$$dp_i = [dsv(i) + dsv(i + 1)]/2$$

$$x_i = \text{Percent by weight in size range}$$

Table 3.2 Comparison of Various Bed-Material Size Analyses

Material	Sample Number	Through 3200 on 1400 (X by wt.)	Through 1400 on 850 (X by wt.)	Through 850 on 600 (X by wt.)	Through 600 on 150 (X by wt.)	Through 150 (X by wt.)	Average Particle Size* (um)	Summation (X by wt.)	Extremes (High/Low)
Brick Used in ENCA Cold Model	---	0	92.8†	6.9	0.2	0.15	993.2	88.2	---
Fresh	---	0	81.3	16.1	2.5	0.1	923.4	99.9	---
Aged (5 h)	---	0	80.8	15.9	3.3	0.1	912.7	100.0	---
Aged (10 h)	---	0	75.1	54.3	20.5	0.1	648.5	99.9	---
Aged (130 h)	---	0	25.1	54.3	20.5	0.1	648.5	99.9	---
Continuous Pilot-Plant Gasifier Bed Sample†									
Run 6:									
Variation in 3200-1400 size	50405	28.8	40.7	19.5	10.9	0.0	954.5	99.9	High
	50614	7.1	49.6	28.5	14.5	0.2	796.6	99.7	Low
Variation in 1400-850 size	50578	9.3	53.3	22.3	14.9	0.1	818.6	99.8	High
	50659	21.4	38.6	27.8	13.2	0.0	873.4	100.0	Low
Variation in 850-600 size	50592	10.2	45.4	29.8	14.6	0.0	801.1	100.0	High
	50405	28.8	40.7	19.5	10.9	0.0	954.5	99.9	Low
Variation in 600-150 size	50700	15.5	40.5	22.6	21.4	0.0	763.5	100.0	High
	50486	15.0	50.5	24.6	9.9	0.0	894.9	100.0	Low
Variation in less than 150 size	50411	20.5	46.2	20.5	10.3	2.6	922.2	97.5	High
	50477	13.2	50.5	25.3	11.0	0.0	870.6	100.0	Low
Variation in average size	50405	28.8	40.7	19.5	10.9	0.0	954.5	99.9	High
	50700	15.5	40.5	22.6	21.4	0.0	763.5	100.0	Low
Run 7:									
Variation in 3200-1400 size	51001	37.5	34.4	16.1	12.0	0.0	989.2	100.0	High
	51184	12.5	39.4	24.4	21.6	0.2	729.0	99.9	Low
Variation in 1400-850 size	51133	22.4	43.4	19.7	14.5	0.0	876.0	100.0	High
	51027	28.9	29.2	20.8	20.9	0.1	811.8	99.8	Low
Variation in 850-600 size	51170	13.2	36.1	26.1	24.7	0.0	716.6	100.1	High
	51001	37.5	34.4	16.1	12.0	0.0	989.2	100.0	Low
Variation in 600-150 size	51036	23.4	29.4	21.8	25.2	0.2	747.1	99.8	High
	51133	22.4	43.4	19.7	14.5	0.0	876.0	100.0	Low

$$\text{Average Particle Size} = dp_n = \frac{1}{\sum_{i=1}^n \frac{1}{dp_i}}$$

where

$$dp_1 = [d_{av}(1) + d_{av}(1 + 1)]/2$$

$$x_1 = \text{Percent by weight in size range}$$

†Through 1200 on 850 - brick only.

‡For the crushed brick 0.13 is assumed to be less than 150 um.

§Sample size analyses were chosen to illustrate the range of size distribution reported. All sizes are in micrometers.

Table 3.2 Comparison of Various Bed-Material Size Analyses (Cont)

Material	Sample Number	Through 3200 on 1400 (Σ by wt.)	Through 1400 on 850 (Σ by wt.)	Through 850 on 600 (Σ by wt.)	Through 600 on 150 (Σ by wt.)	Through 150 (Σ by wt.)	Average Particle Size ^a (μm)	Summation (Σ by wt.)	Extremes (High/Low)
Variation in less than 150 size	51184	12.5	39.4	24.4	23.6	0.2	729.0	99.9	High
Variation in average size	51156	16.1	42.4	23.4	18.0	0.0	799.4	99.9	Low
	51001	37.5	34.4	16.1	12.0	0.0	989.2	100.0	High
	51170	13.2	36.1	26.1	24.7	0.0	716.6	100.1	Low
FWNC Candidate Bed Materials									
Limestones									
Franklin (8-26 mesh)	M22368	0.4	46.6	43.7	7.4	1.9	806.7	98.1	—
Basic Oxygen Furnace Slag (6 x 50 mesh)	M22299	60.2	16.4	10.1	13.3	0	1109.3	100.0	—
Basic Oxygen Furnace Slag (6 x 30 mesh)	M22299	62.8	22.0	14.4	0.7	0	1456.3	99.9	—
Basic Oxygen Furnace Slag (Blend) (16 x 50 mesh and 6 x 16 mesh)	M22299	30.3	18.6	20.2	30.9	0	714.4	100.0	—

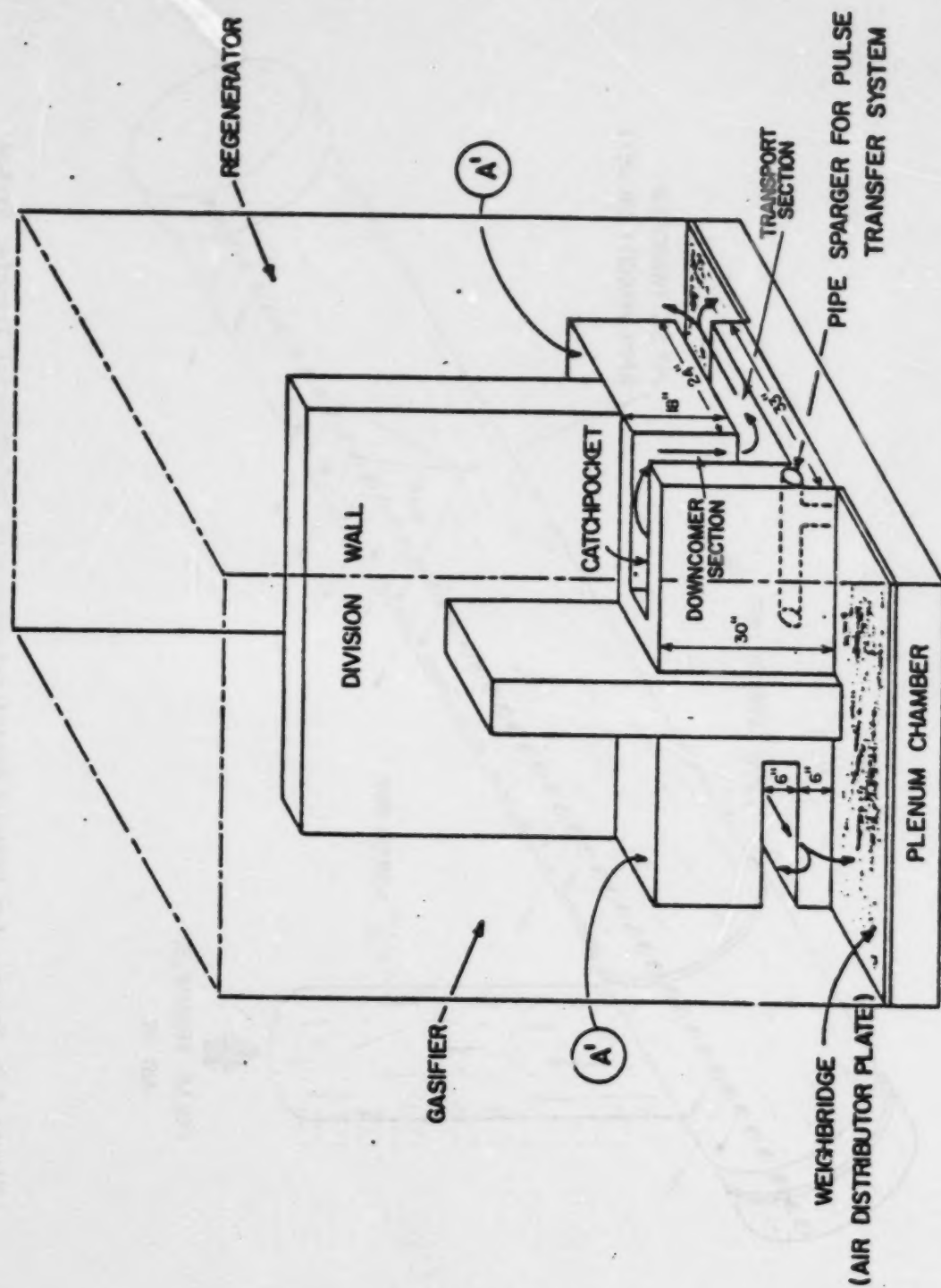


Figure 3.1 Primary Gasifier-Regenerator Bed-Material Transfer System--Original Configuration

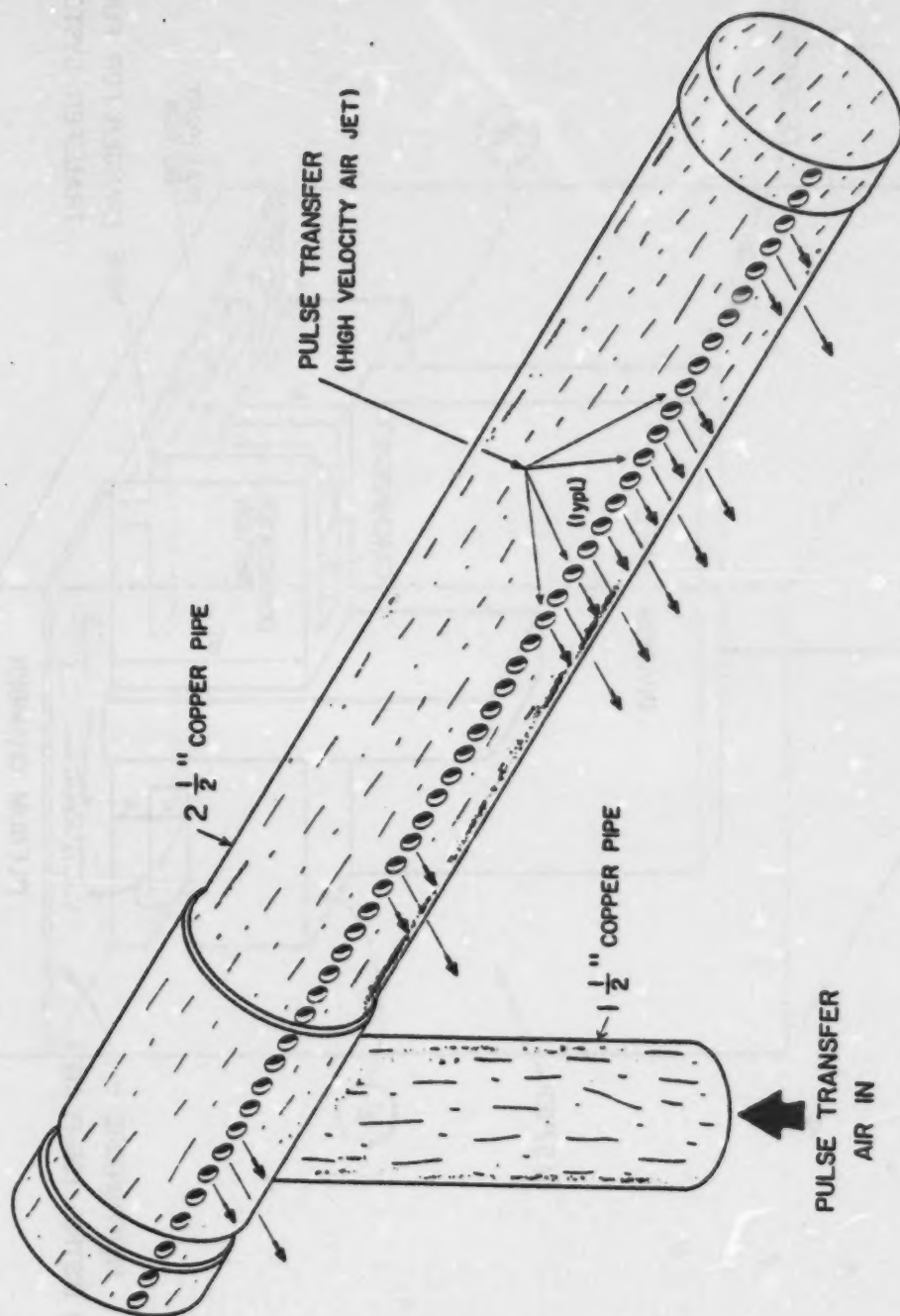
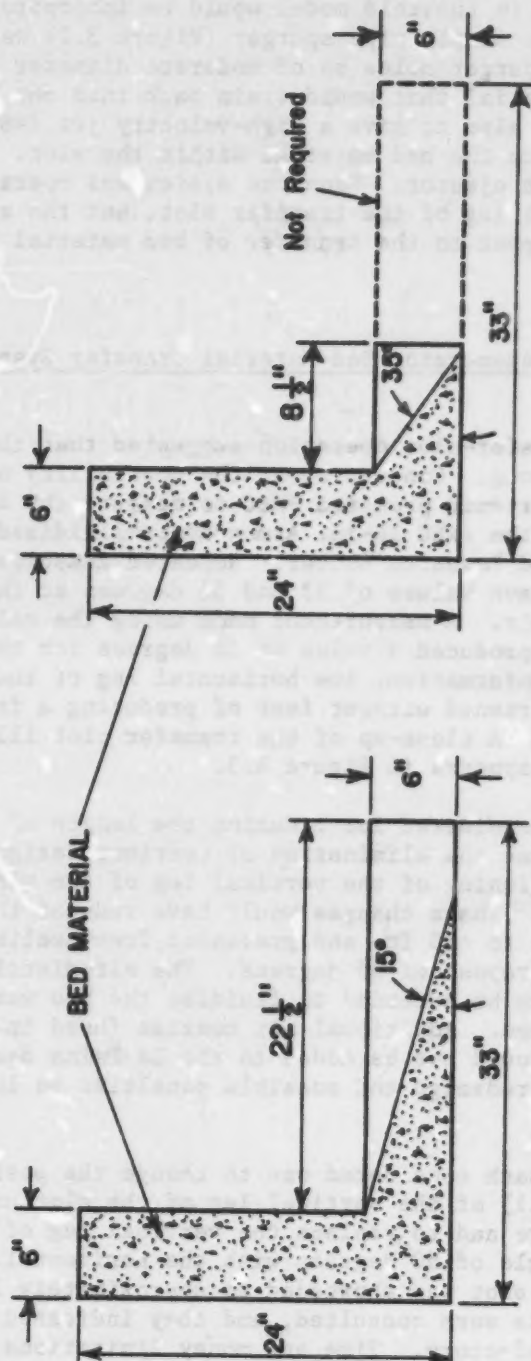


Figure 3.2 Sparger for Primary Gasifier-Regenerator Bed-Material Transfer System



$$\text{HORIZONTAL LEG} = \frac{6 \text{ in.}}{\tan 35^\circ} = 8 \frac{1}{2} \text{ in.}$$

35-DEGREE ANGLE OF REPOSE

$$\text{HORIZONTAL LEG} = \frac{6 \text{ in.}}{\tan 15^\circ} = 22 \frac{1}{2} \text{ in.}$$

15-DEGREE ANGLE OF REPOSE

Figure 3.3 Angle-of-Repose Comparison for Primary Gasifier-Regenerator Bed-Material Transfer System--Original Configuration

Since no sparger design was selected by the Engineering Department, the sparger that operated best in the cold model would be incorporated into the La Palma design. Initially, a simple pipe sparger (Figure 3.2) was designed. Logic suggested that the sparger holes be of moderate diameter ($\approx 1/8$ in.) to minimize the amount of material that would drain back into the sparger when the system was inoperative and also to give a high-velocity jet (≈ 600 ft/s) that would apply a large force to the bed material within the slot. This sparger would act very much like an ejector. When the system was operated, bed material quickly filled the vertical leg of the transfer slot, but the spargers were quite ineffective with respect to the transfer of bed material from the horizontal leg of the slot.

3.2.2 Primary Gasifier-Regenerator Bed-Material Transfer System— First Change

Review of the transfer-slot operation suggested that the horizontal leg of the slot was much too long. Concern about the possibility of freewheeling if the slot length was shortened prompted FWEC to measure the hot angle of repose of bed material from the FWEC 18-in. Atmospheric Fluidized-Bed Combustor located at the John Blizzard Research Center. Repeated measurements of the bed-material angle of repose gave values of 33 and 32 degrees at temperatures of 1300 and 1600°F respectively. A measurement made using the cold-model limestone at room temperature produced a value of 35 degrees for the angle of repose. Based on FWEC's information, the horizontal leg of the bed-material transfer slot could be shortened without fear of producing a freewheeling condition within the slot. A close-up of the transfer slot illustrating the 35-degree angle of repose appears in Figure 3.3.

The first method considered for reducing the length of the horizontal leg of the transfer slot was the elimination of sections designated (A') in Figure 3.1 and the repositioning of the vertical leg of the slot until it touched the division wall. These changes would have reduced the length of the horizontal leg of the slot to ≈ 10 in. and prevented freewheeling when using a material with an angle of repose of 35 degrees. The air-distributor plates in both beds would have had to be extended to fluidize the bed material in each new area (A') that was added. Additional air nozzles (used in the actual CAFB for fluidizing the beds) could not be added to the La Palma design without requiring a great deal of redesign and possible penalties on long-lead items already ordered.

An alternate approach considered was to change the position of the catchpocket (see Figure 3.1) of the vertical leg of the slot until it touched the division wall as before and to replace the vertical leg of the slot with one which sloped at an angle of 50 degrees with the horizontal. The length of the horizontal leg of the slot was shortened to approximately 12 in. using this method. Refractory experts were consulted, and they indicated that such an arrangement would be satisfactory. Time and money limitations dictated that all changes would be made to the regenerator-to-gasifier slot only. The slotwork within the cold model was appropriately altered. The adjusted slotwork configuration appears in Figure 3.4.

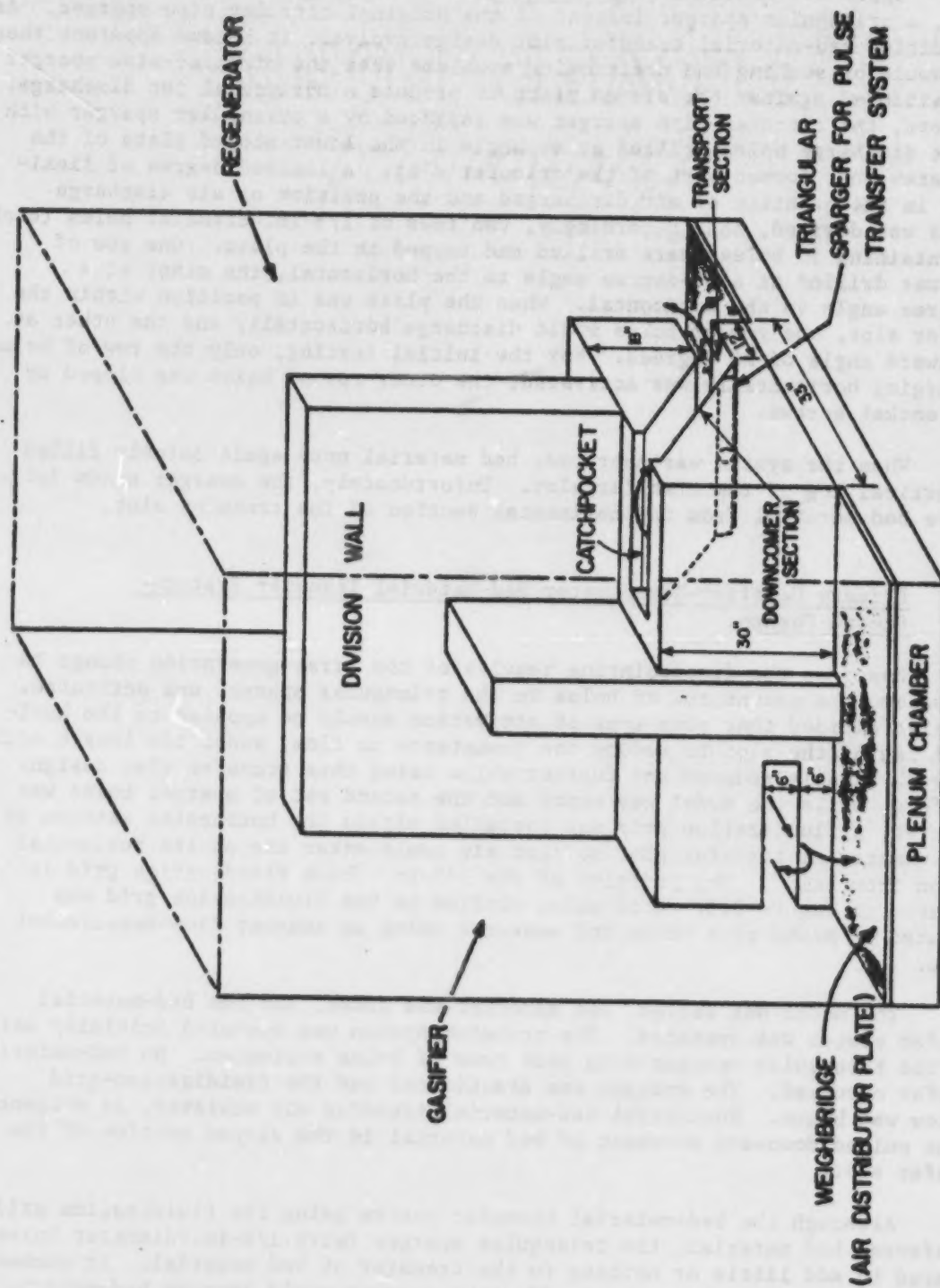


Figure 3.4 Primary Gasifier-Regenerator Bed-Material Transfer System--First Change

Figure 3.4 contains an additional variation from the original design, namely, a triangular sparger instead of the original circular pipe sparger. As the modified bed-material transfer slot design evolved, it became apparent that there would be sealing and positioning problems when the circular-pipe sparger was positioned against the sloped plate to produce a horizontal jet discharge. Therefore, the circular-pipe sparger was replaced by a triangular sparger with the jet discharge holes drilled at an angle in the lower sloped plate of the two plates that formed part of the transfer slot. A limited degree of flexibility in the quantity of air discharged and the position of air discharge outlets was desired, and, accordingly, two rows of 1/8-in.-diameter holes (each row containing 50 holes) were drilled and tapped in the plate. One row of holes was drilled at a 50-degree angle to the horizontal, the other at a 40-degree angle to the horizontal. When the plate was in position within the transfer slot, one row of holes would discharge horizontally and the other at a downward angle of 10 degrees. For the initial testing, only the row of holes discharging horizontally was activated; the other row of holes was closed by small socket screws.

When the system was operated, bed material once again quickly filled the vertical leg of the transfer slot. Unfortunately, the sparger again failed to move bed material from the horizontal section of the transfer slot.

3.2.3 Primary Gasifier-Regenerator Bed-Material Transfer System— Second Change

Based on the disappointing results of the first-generation change to the system, the second row of holes in the triangular sparger was activated. FWEC also decided that some type of activation should be applied to the horizontal leg of the slot to reduce the resistance to flow, since its length could not be physically reduced any further while using this transfer slot design. Therefore, while the model was empty and the second set of sparger holes was activated, a fluidization grid was installed within the horizontal section of the bed-material transfer slot so that air could enter the entire horizontal section from below. The position of the 1/2-in.-thick fluidization grid is indicated in Figure 3.5. Activation airflow to the fluidization grid was regulated by means of a valve and measured using an annubar flow-measurement device.

The model was sealed, bed material was added, and the bed-material transfer system was operated. The transfer system was operated initially using only the triangular sparger with both rows of holes activated. No bed-material transfer occurred. The sparger was deactivated and the fluidization-grid airflow was begun. Successful bed-material transfer was achieved, as evidenced by the pulsed downward movement of bed material in the sloped section of the transfer slot.

Although the bed-material transfer system using the fluidization grid transferred bed material, the triangular sparger (with 1/8-in.-diameter holes) appeared to add little or nothing to the transfer of bed material. It seemed reasonable to assume that a more effective sparger would improve bed-material

transfer by more easily evacuating the horizontal leg of the bed-material transfer slot. In an attempt to increase the mass flow (and thus the horizontal force component) from the triangular sparger, the 50 holes in the horizontal discharge row of sparger holes were increased from 1/8- to 9/32-in. diameter. The system was operated without the fluidization grid activated. Bed-material transfer was achieved, as shown by an increase in bed height in the gasifier, a corresponding decrease in the regenerator, and the visual evidence of bed material descending in the sloped section of the transfer slot. The system was also operated with only the fluidization grid activated and with both the sparger and fluidization grid activated. Both bed-material activation methods effectively transferred bed material, but the sparger accomplished this transfer at a lower air-consumption rate. Nevertheless, a considerable portion of the sparger and/or fluidization-grid air appeared to be diverted upward along the sloped leg of the transfer slot and into the regenerator. In addition, it was postulated that a portion of the jet-discharge momentum was destroyed against the bottom surface of the horizontal slot because of the low position of the sparger holes on the sloped plate.

3.2.4 Primary Gasifier-Regenerator Bed-Material Transfer System— Third Change

Based on the desirability of reducing the volume of air diverted upward along the sloped leg of the transfer slot and the difficulties involved in adjusting the height of the air discharge holes above the bottom surface of the horizontal slot within a sloped plate, two changes were made to the transfer system. First, in an attempt to reduce the air leakage upward along the sloped section of the slot, the slot width was maintained at 6 in. at the catchpocket level but reduced to 5 in. at the lowest section, which intersects the horizontal slot. This arrangement is presented in Figure 3.5.

Figure 3.5 also illustrates the dimensions and position of the "new" rectangular sparger designed to replace the triangular sparger. This sparger is easily removable, and the position and number of the air discharge holes can be easily altered. It was also felt that the larger length-to-height ratio possible in the rectangular sparger might minimize any problems with the bed material's sifting into the relatively large (9/32-in.-diameter) sparger holes.

Operation of the revised system was successful, and the material appeared to move evenly downward in the sloped slot with each activating air pulse. The system was operated for several minutes, and a bed-material transfer rate was calculated from the change in bed heights in both the gasifier and regenerator. Disappointingly, the rate appeared to be only 3000 to 4000 lb/h. As an additional confirmation of this transfer rate, another test was conducted, in which the pulsed transfer system transferred material from the regenerator to the gasifier while the external bed loading system simultaneously transferred material back to the regenerator. (The external bed loading system consists of a vibrating feeder, a bucket elevator, and a material return chute. The bed-material removal rate from the vibrating feeder was set at the maximum.) The bed-material removal rate from the gasifier (from the vibrating feeder), measured as weight per time, was maintained at 4104 lb/h. Bed levels in both the

gasifier and regenerator were recorded before and after the test. The bed levels were essentially unchanged, indicating that the pulsed transfer system was transferring material at a rate of approximately 4100 lb/h. This bed-material transfer rate was only one-eighth the required rate; thus further modifications to the bed-material transfer slot and the sparger were deemed necessary.

3.2.5 Primary Gasifier-Regenerator Bed-Material Transfer System-- Fourth Change

It was observed that during testing of the bed-material transfer system described above (Figure 3.5), bed material slid downward along the sloped downcomer section of the slot over only the upper half of the width of the slot and that less than one-half the width of the horizontal section was active. To increase the percentage of active sloped downcomer and horizontal sections, the first changes made to the bed-material transfer slots were a reduction in the width of the sloped section of the transfer slot from 6 to 4-1/4 in. and a reduction in the width of the horizontal section from 5-1/4 to 4-1/2 in. In addition, the angle formed between the sloped section of the slot and a horizontal plane was reset at 50 degrees.

During preliminary testing, it was noticed that a significant percentage of gas (air) escaped upward along the upper face of the sloped downcomer. In an effort to reduce the volume of gas escaping in this manner, the fluidization grid was removed (leaving only the sparger as the bed-material transfer motivating force), and a small wedge piece was introduced at the bottom of the sloped downcomer section of the slot, reducing the width of the opening into the horizontal section to 3-1/8 in. The new bed-material slot geometry appears in Figure 3.6.

As stated previously, the bed-material transfer rate obtained using the rectangular sparger containing fifty 9/32-in.-diameter holes was only 4000 lb/h. Under the assumption that insufficient driving force was being employed, two additional rows (each containing twenty-five 9/32-in.-diameter holes) were added to the rectangular sparger. The vertical distances of the rows of holes from the bottom of the horizontal slot became:

- 25 holes at 2 in.
- 50 holes at 2-3/4 in.
- 25 holes at 3-1/2 in.

The revised bed-material transfer system was operated, and some of the changes that had been incorporated were effective, while others were not. For instance, a greater percentage of both the sloped and horizontal sections of the transfer slot appeared to be active; however, no decrease in gas loss along the upper face of the sloped downcomer was observed. A possible explanation is that the additional gas (air) input per pulse (caused by the additional number of gas discharge holes in the sparger) negated to a large extent the expected

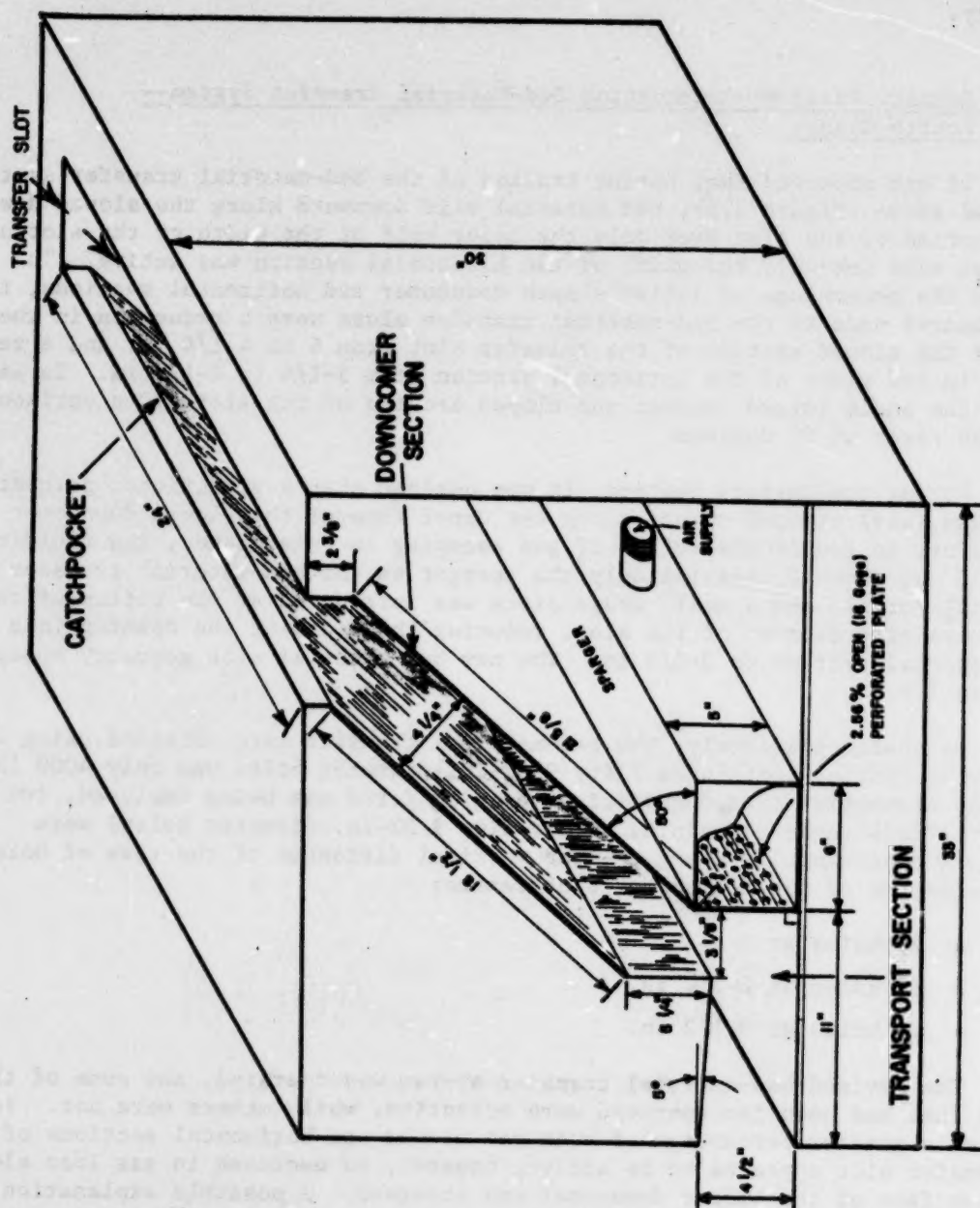


Figure 3.6 Primary Gasifier-Regenerator Bed-Material Transfer System--Fourth Change

reduction in gas loss provided by the better packing of bed material at the sloped downcomer exit. During these preliminary tests, the bed-material transfer system performance deteriorated with increased time of operation. The system was, therefore, deactivated, the beds drained, and the sparger removed. Upon examination, it was discovered that a considerable quantity of bed material had drained back through the 9/32-in.-diameter holes within the sparger. Since sifting of bed material into the sparger was to be avoided and since preliminary tests had indicated that too much air was being introduced into the sparger, it was decided that the front face of the sparger (containing the three rows of 9/32-in.-diameter holes) would be replaced with a piece of perforated plate containing 1/16-in.-diameter holes on a 0.375-in. equilateral triangular pitch (2.56 percent free area). Tests using the new sparger (illustrated in Figure 3.6) showed it to have operating performance comparable to the sparger with the 9/32-in.-diameter holes, while allowing only minimal sifting of bed material into the sparger. The perforated-plate sparger was used for all subsequent tests.

The bed-material transfer rate using the perforated-plate sparger appeared to increase significantly over that obtained previously, as evidenced by an increase in gasifier bed height during a test, although the external bed-material recycle system was operating at maximum (≈ 4100 lb/h). This rise in the gasifier bed height indicated that bed material was being transferred from the regenerator to the gasifier by the pulsed transfer system faster than it could be recycled externally to the regenerator.

Since previous tests had shown a marked bed-material transfer-rate dependence on bed height, it was necessary to increase the transfer rate of the external bed-material recycle system to maintain essentially constant bed heights during transfer. Several changes to the recycle system were required before an external bed-material recycle rate of 23,000 lb/h was obtained. Under this recycle-rate condition, only small changes in bed height (approximately 2 to 4 in.) of the gasifier were obtained, indicating that the true pulsed transfer rate was approximately 25,000 lb/h. A series of calibration tests was performed to verify the rates obtained. Since the bucket elevator used by the external recycle system is rated at a maximum throughput of approximately 23,000 lb/h, further modifications to increase the external bed-material recycle rate were not deemed justifiable.

At this point, testing was begun on the tests outlined in the variable testing matrix appearing in Table 3.3. The three variables considered in the matrix are the pulse frequency (number of pulses per unit time), the pulse duration (actual time of airflow), and the sparger pressure. Testing began with the frequency tests, and after several tests a developing problem became apparent. The bed-material transfer rate was suddenly and drastically reduced. The bed-material transfer slot was disassembled to examine the perforated-plate sparger. Bed material had obstructed a significant portion of the sparger open area, even though the 1/16-in.-diameter holes are considerably smaller than the 9/32-in.-diameter holes used in previous spargers and even though sifting of bed material through the 1/16-in.-diameter holes had not been observed before. (The air-distributor plates within the cold model are made of the same perforated plate, and no sifting into the plenum chamber has ever been observed.)

Table 3.3 Scheduled Primary Gasifier-Regenerator Bed-Material Transfer Slot Variable Testing Matrix

Test No.	Pulse On-Time (Setting)	Pulse Off-Time (Setting)	Sparger ΔP (lb/in ² g)
F0, F0R	0	0	6.5
F1, F1R	0	1	6.5
F2, F2R	0	2	6.5
F3, F3R	0	3	6.5
F4, F4R	0	4	6.5
F5, F5R	0	5	6.5
F6, F6R	0	6	6.5
F7, F7R	0	7	6.5
F8, F8R	0	8	6.5
F9, F9R	0	9	6.5
F10, F10R,	0	10	6.5
D0, D0R	0	2	6.5
D1, D1R	1	2	6.5
D2, D2R	2	2	6.5
D3, D3R	3	2	6.5
D4, D4R	4	2	6.5
D6, D6R	6	2	6.6
D8, D8R	8	2	6.5
D10, D10R	10	2	6.5
P _{6.5} , P _{6.5} R	0	2	6.5
P _{5.5} , P _{5.5} R	0	2	5.5
P _{4.5} , P _{4.5} R	0	2	4.5
P _{3.5} , P _{3.5} R	0	2	3.5
P _{2.5} , P _{2.5} R	0	2	2.5

*Note: Frequency tests were also performed with a bleed air system in use. These tests are suffixed with an (A), e.g., F0(A).

It was postulated that the back pressure of the bed following a pressure pulse might have forced bed material into the sparger. To prevent such sparger plugging, a small bleed air was applied to the sparger and set at a pressure of approximately 2 lb/in²g. This pressure was sufficient to counteract the back pressure of the bed from forcing the bed material into the sparger after each pulse. All subsequent frequency tests were performed while the sparger bleed air was activated, and no further sparger plugging was observed.

All frequency variation tests (F0 to F10) and repeats (FOR to F10R) were completed.* Although extensive data reduction was not available, preliminary examination of the data indicated that for most frequency values the bed-material transfer rate increased as the pulse frequency decreased. A marked decrease in system efficiency was observed near the minimum frequency setting [F0(A)] when the bleed-air system was in operation. At this frequency setting a considerable portion of the transfer air rose upward along the sloped section and was ineffective in promoting bed-material transfer. Although approximately the same amount of bed material was transferred as in tests F1(A) and F3/4(A), more transport air was required to accomplish the transport, resulting in a lower efficiency.

3.3 ALTERNATE GASIFIER-REGENERATOR BED-MATERIAL TRANSFER SYSTEM

3.3.1 Alternate Gasifier-Regenerator Bed-Material Transfer System-- Original Configuration

On June 23, 1976, representatives of ERCA and Exxon met at the Foster Wheeler John Blizzard Research Center to observe a demonstration of the Primary Gasifier-Regenerator Bed-Material Transfer System--Fourth Generation. After the demonstration, ERCA commented that they felt that too much air was escaping into the regenerator upward along the sloped downcomer section and that the system's reliability could be improved. FWEC felt that the volume of air escaping upward along the sloped downcomer section of the slot was directly caused by the shallow 50-degree angle of the slope and could be greatly reduced (if not eliminated) by the use of a steeper, sloped section. FWEC agreed with ERCA, however, that the system reliability and reproducibility had not been optimized. Previous testing indicated a strong bed-material transfer rate dependence on both bed height and bed-material property characteristics (e.g., particle size distribution, particle shape, etc.). In fact, the bed-material transfer rate dependence on bed height was the primary reason why the external recycle system was used during testing. ERCA and Exxon had performed some bed-material transfer calculations and stated that the results indicated that the present, rectangular bed-material transfer slot should be replaced with several 5- to 6-in.-diameter circular slots.

Based on considerations of cost, time, and model availability, FWEC decided that the best compromise would be to perform the remainder of the variable testing matrix outlined in Table 3.3 on the Primary Bed-Material Transfer System and to also perform tests on a single circular-slot configuration.

*Frequency tests were also performed with the bleed-air system in use. These tests are suffixed with an (A), e.g., F0(A).

The circular-slot configuration, which was developed by ERCA/Exxon with input from FWEC, appears in Figure 3.7. This system operated in a similar manner to the Primary Gasifier-Regenerator Bed-Material Transfer System except that it transferred material from the gasifier to the regenerator in the cold model. Bed material from the gasifier entered the top of the 5-in.-diameter tube and slid downward to the bottom. This defluidized bed material was entrained in the airstream issuing from the 1/2-in.-diameter tube and was propelled from the 3-in.-diameter tube into the regenerator. This system operated with either a continuous airstream coming from the 1/2-in.-diameter tube or with pulses of air (as used with the Primary Gasifier-Regenerator Bed-Material Transfer System). When air pulses were used, bleed air was required. The extent of insertion of the 1/2-in.-diameter tube within the 3-in. tube was also variable.

The first test performed using this Alternate Bed-Material Transfer System illustrated a defect within this design. A major reason for installing the 3-in.-diameter tube at an upward angle of 20 degrees with the horizontal was to enable the tube to be "rodded out" from the plenum chamber. Unfortunately, unless a constant bleed air was maintained within the 1/2-in.-diameter tube, bed material would drain into that tube and block it. When this happened, even a pressure in excess of 20 lb/in²g would not evacuate the bed material from the tube. Almost the entire regenerator bed had to be removed before the tube could be removed. To prevent a recurrence of this problem, a small section of 30-mesh screening was installed within the tube approximately 1 in. from its exit. Although the model was operated in a batchwise mode after that time, the bed-material drainage problem did not recur. As previously done, a new external recycle system (from regenerator to gasifier) was installed to better control the bed heights in both beds during a test and to obtain a better measurement of the bed-material transfer rate.

Preliminary bed-material transfer rates obtained using the Alternate Bed-Material Transfer System were disappointing. Several trial tests were performed using both the continuous and pulsing modes of operation. Fairly repeatable maximum bed-material transfer rates of only 2000 to 3000 lb/h were obtained. A direct measurement of the descent rate within the 5-in.-diameter tube indicated a rate of 0.4 to 0.5 in./s, which corresponded to a mass transfer rate of approximately 1600 to 2000 lb/h (assuming a bulk density of 100 lb/ft³). Considering the greater frictional drag at the tube wall, the directly and indirectly measured bed-material transfer rates were in good agreement.

From these preliminary tests performed using the Alternate Gasifier-Regenerator Bed-Material Transfer System, it appeared that changes in process variables alone would not increase the bed-material transfer rate to the minimum acceptable value of 10,000 lb/h per slot and that changes in the transfer slot geometry itself would be required. While the Alternate System was being studied to ascertain where and what changes should be made, the remaining tests (pulse duration and sparger pressure) were scheduled to be performed using the Primary Gasifier-Regenerator Bed-Material Transfer System so that the maximum performance data on both systems would be available for evaluation.

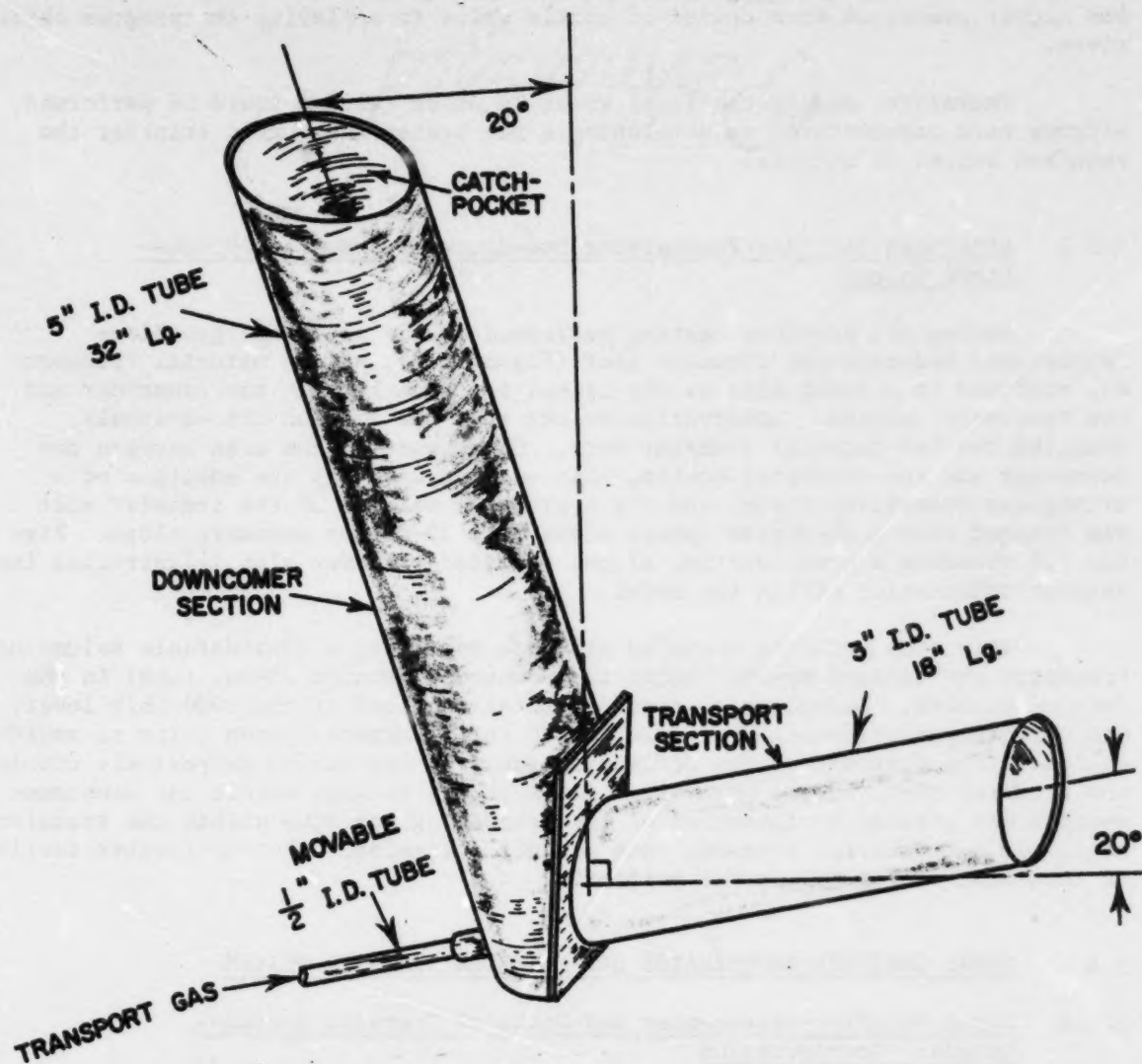


Figure 3.7 Alternate Gasifier-Regenerator Bed-Material Transfer Slot--Original Configuration

When testing resumed, duration tests D0(A) and D2(A) were performed. Results obtained during these two duration tests indicated that an increase in pulse duration did not improve system performance (bed-material flow rate). The use of additional activating gas to attain this flow rate was required. Thus the remaining duration tests outlined in Table 3.3 were not performed. Similarly, since the sparger operating pressure was already at 6.5 lb/in²g and the system was not achieving the desired bed-material flow rate, tests at lower and higher pressures were deemed of little value in achieving the program objectives.

Therefore, during the final weeks in which testing could be performed, efforts were concentrated on developing a new system that would transfer the required amount of material.

3.3.2 Alternate Gasifier-Regenerator Bed-Material Transfer System-- First Change

During the previous testing performed on the alternate gasifier-regenerator bed-material transfer slot (Figure 3.7), active material transport was confined to a small area at the transition bend between the downcomer and the transport section. Observation showed that the section was obviously limiting the bed-material transfer rate. Consequently, the area between the downcomer and the transport section slot was increased by the addition of a triangular transition piece, and the horizontal section of the transfer slot was changed from a 20-degree upward slope to a 20-degree downward slope. Figure 3.8 presents a cross section of the modified transfer slot illustrating its angular orientation within the model.

When this modified transfer slot was operated, a considerable volume of transport gas escaped upward within the downcomer section (5-in. tube) in the form of bubbles. Bed-material transfer rates remained at the 2000 lb/h level, and performance in general was inferior to the Alternate System prior to modifications. The position of the activating gas tube was varied extensively within the transfer slot, but to no avail. Although air leakage within the downcomer section was reduced by insertion of the activating gas tube within the transfer slot, the bed-material transfer rate was not increased. Thus no further testing of this slot configuration was performed.

3.4 FINAL GASIFIER-REGENERATOR BED-MATERIAL TRANSFER SYSTEM

3.4.1 Final Gasifier-Regenerator Bed-Material Transfer System-- Original Configuration

Experience with all of the slot configurations used did, however, indicate a direction for a new design. For instance, tests on the original and modified alternate gasifier-regenerator bed-material transfer systems indicated that the downcomer section of the slot is very sensitive to angular orientation and that as steep an angle as possible is required. In addition, the Alternate Bed-Material Transfer System highlighted the virtues of modularization. Based

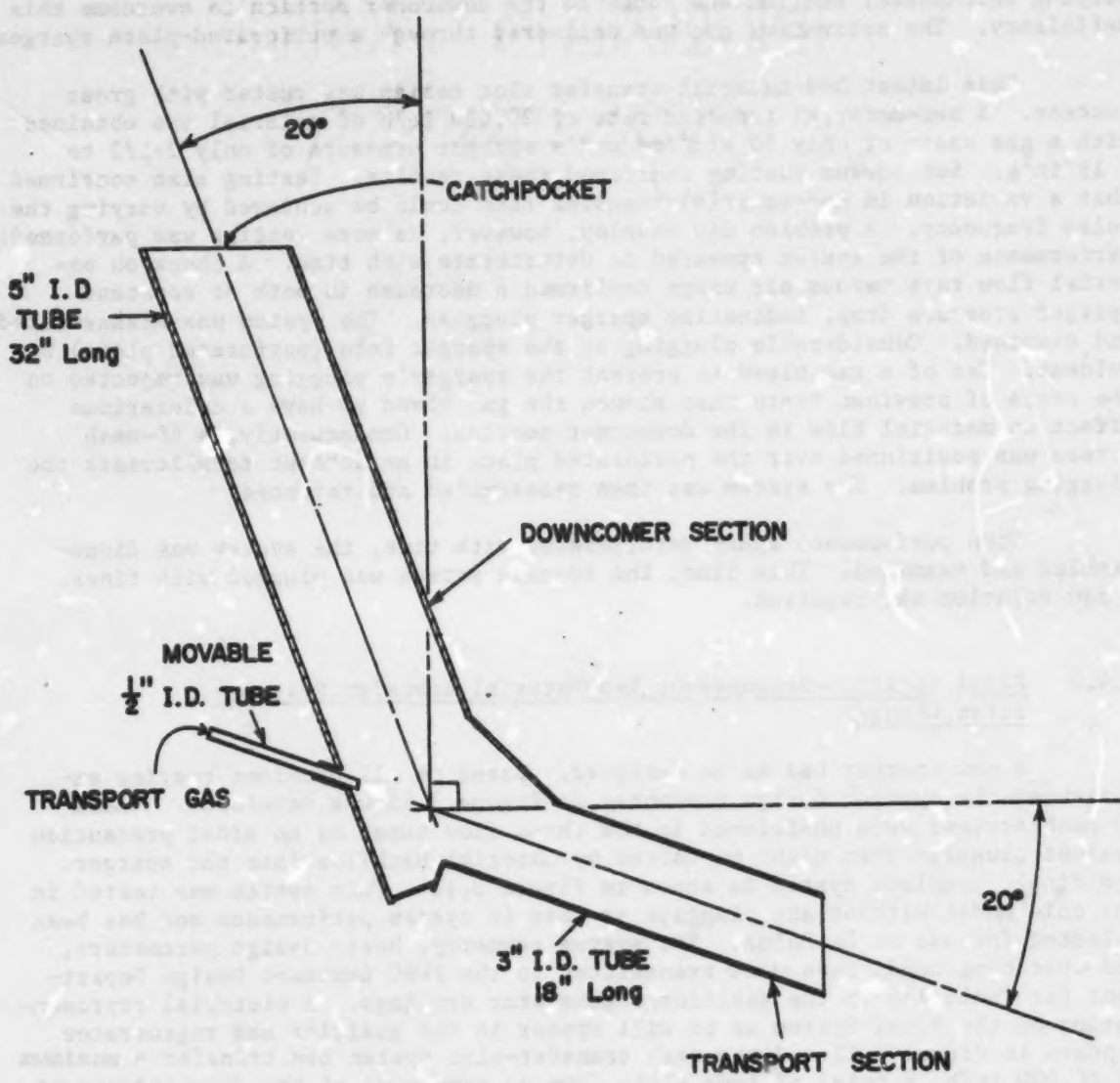


Figure 3.8 Alternate Gasifier-Regenerator Bed-Material Transfer Slot--First Change

on this prior experience, the bed-material transfer slot illustrated in Figure 3.9 was developed. So that the downcomer could be vertical, a section was cut from the gasifier-regenerator division wall. With this constraint the minimum horizontal slot that could be maintained had an overall length of 18 in. The 3-1/2 in. by 6 in. downcomer opening was now 8 in. from the fluidized bed, and material feed from the bed was not able to keep the downcomer filled. The sloping catchpocket section was added to the downcomer section to overcome this deficiency. The activating gas was delivered through a perforated-plate sparger.

This latest bed-material transfer slot design was tested with great success. A bed-material transfer rate of 20,000 lb/h of material was obtained with a gas usage of only 50 sft³/m* and a sparger pressure of only 2-1/2 to 3 lb/in²g. Subsequent testing confirmed these results. Testing also confirmed that a variation in bed-material transfer rate could be achieved by varying the pulse frequency. A problem did develop, however, as more testing was performed. Performance of the system appeared to deteriorate with time. A check on material flow rate versus air usage confirmed a decrease in both at constant sparger pressure drop, indicating sparger plugging. The system was disassembled and examined. Considerable plugging of the sparger face (perforated plate) was evident. Use of a gas bleed to prevent the sparger's plugging was rejected on the basis of previous tests that showed the gas bleed to have a deleterious effect on material flow in the downcomer section. Consequently, a 60-mesh screen was positioned over the perforated plate in an attempt to alleviate the plugging problem. The system was then reassembled and retested.

When performance again deteriorated with time, the system was disassembled and examined. This time, the 60-mesh screen was plugged with fines. A new solution was required.

3.4.2 Final Gasifier-Regenerator Bed-Material Transfer System-- First Change

A new sparger had to be designed. Based on all previous testing experience, the sparger design presented in Figure 3.10 was developed. Small 30-mesh screens were positioned in the three flow tubes as an added precaution against pluggage that might be caused by material backflow into the sparger. The final, complete system is shown in Figure 3.11. This system was tested in the cold model without any pluggage or loss in system performance and has been selected for use at La Palma. The system geometry, basic design parameters, and operating conditions were transmitted to the FWEC Contract Design Department for inclusion in the gasifier/regenerator drawings. A pictorial representation of the Final System as it will appear in the gasifier and regenerator appears in Figure 3.12. Since each transfer-slot system can transfer a maximum of 20,000 lb/h, a total of four slots (two on each side of the flow-inducement wall) will be used at La Palma to obtain a maximum transfer rate of 40,000 lb/h. Extra air/flue gas nozzles have been located at the outlet of the slots to increase fluidization of the bed material at this point and to help promote bed-material transfer. Based on the nonplugging performance exhibited in the cold-model tests, small screens in the sparger tubes at La Palma were deemed unnecessary.

*Standard conditions are 14.7 lb/in²a and 70°F.

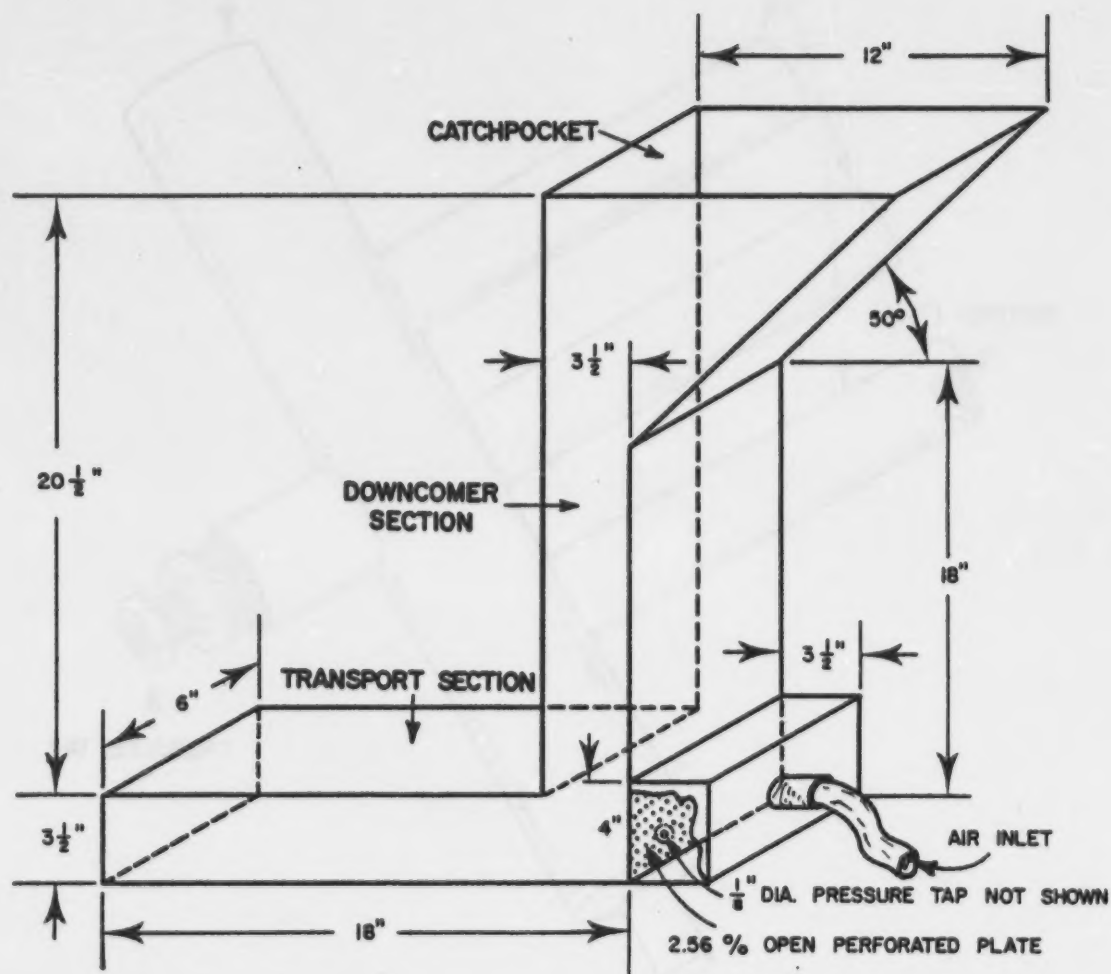


Figure 3.9 Final Gasifier-Regenerator Bed-Material Transfer Slot--
Original Configuration

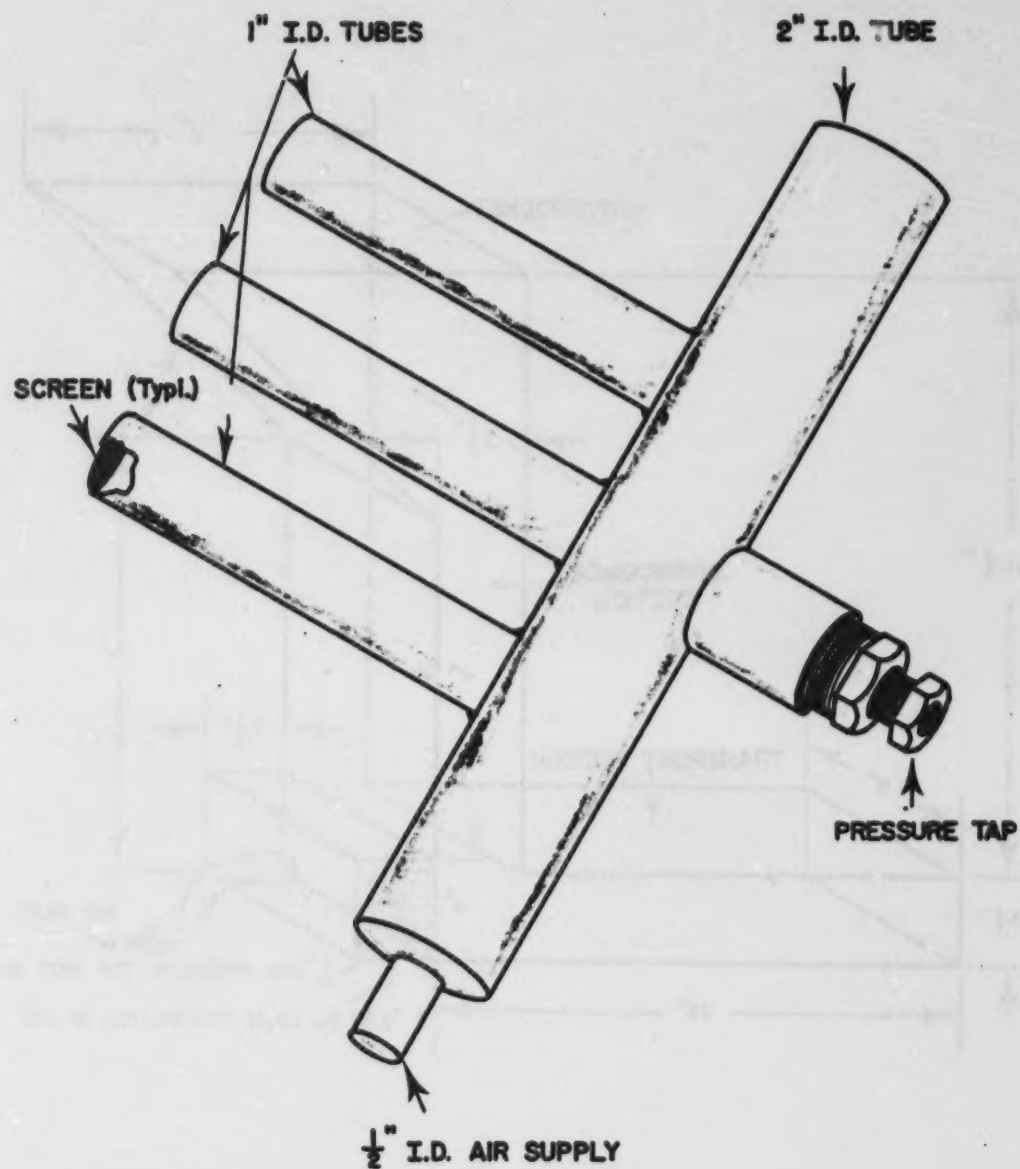


Figure 3.10 Redesigned Sparger for Final Gasifier-Regenerator Bed-Material Transfer System

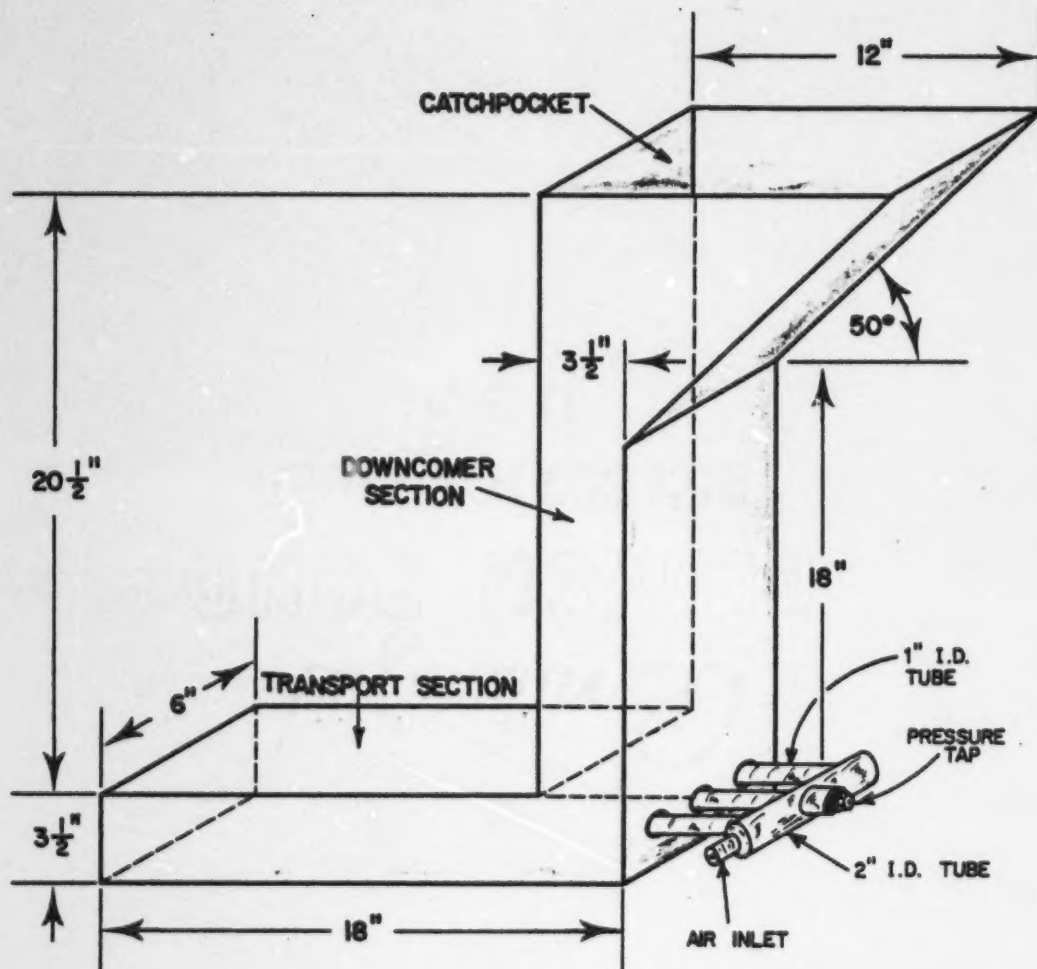
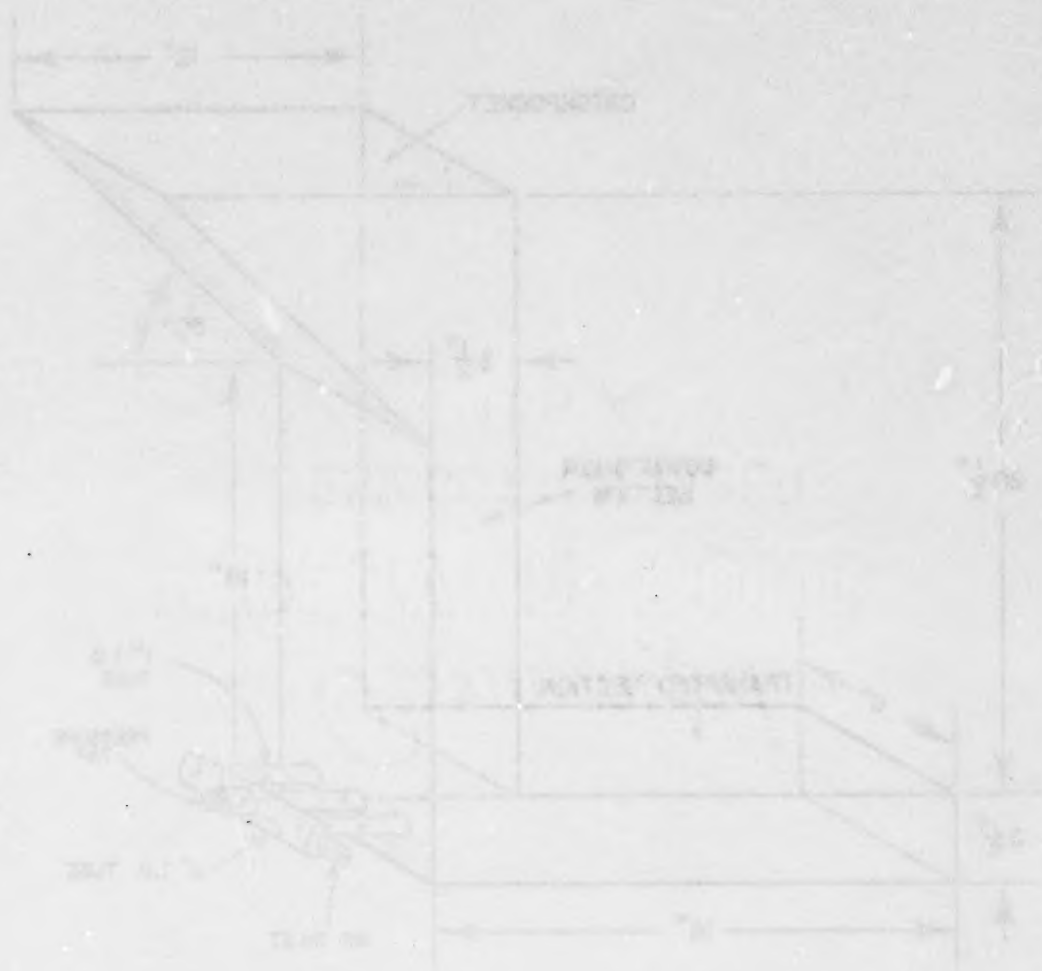


Figure 3.11 Final Gasifier-Regenerator Bed-Material Transfer Slot--
First Change

To permit each transfer slot to operate independently, individual sparger manifolds have been provided. As a result, the two transfer slots on each side of the flow-inducement wall are displaced 3 in. in height from each other, as depicted in Figure 3.12. Although this feature added some complexity to the system, the potential increase in system reliability and flexibility was considered ample compensation.



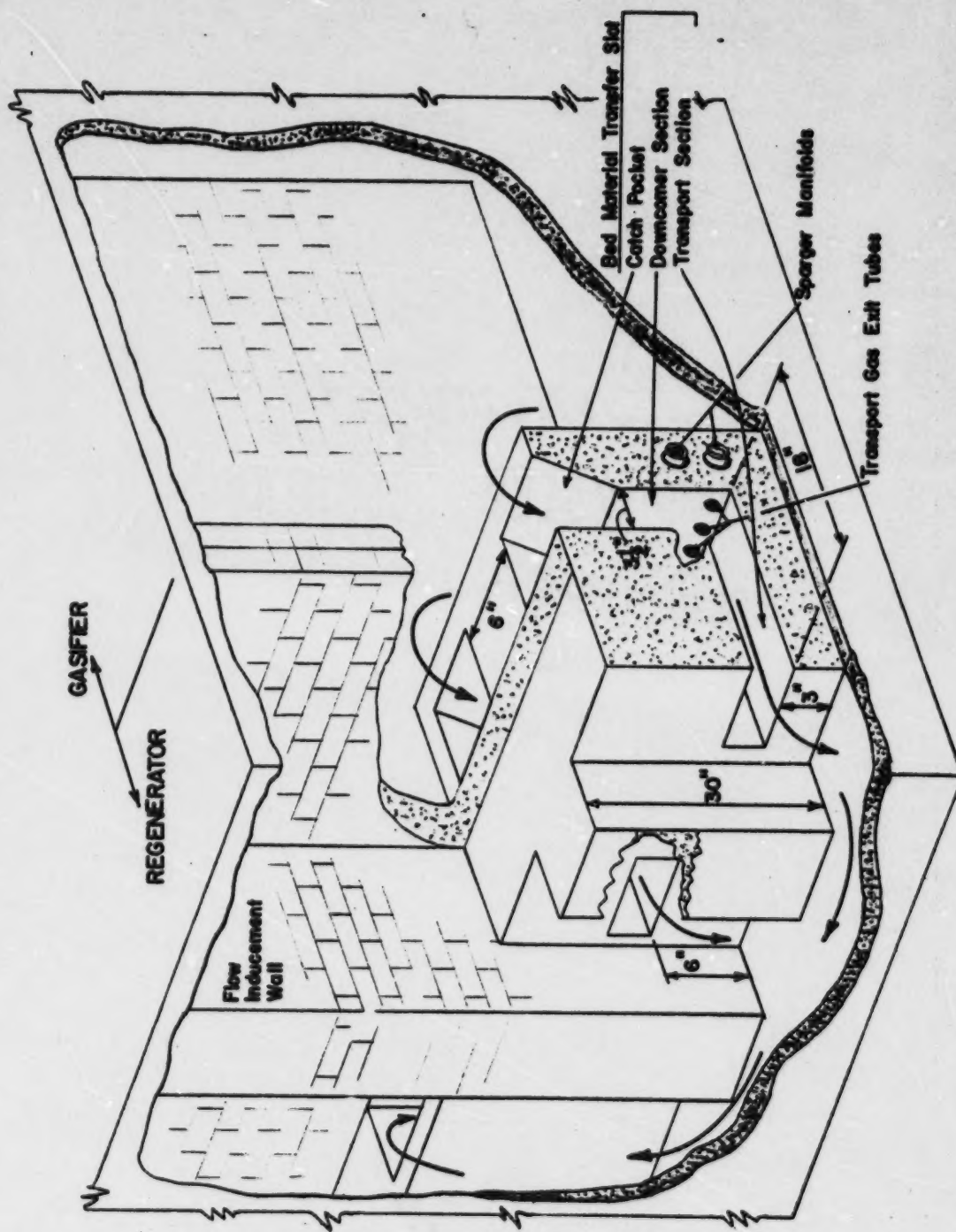


Figure 3.12 Pictorial Representation of La Palma Gasifier-Regenerator Bed-Material Transfer System

Section 4

TEST RESULTS

4.1 GASIFIER-REGENERATOR BED-MATERIAL TRANSFER SYSTEM PERFORMANCE CRITERIA

The purpose of this investigation was to develop a system that would transfer large amounts of bed material per unit time between two operating fluidized beds while utilizing a minimum quantity of activating gas and maintaining a minimum activating gas pressure. The system should also allow only minimal gas leakage back into the "supply" bed and provide an accurate and reliable control of the transfer rate.

4.2 CALIBRATIONS

4.2.1 Weighbridges

Before testing of the original configuration of the Primary Gasifier-Regenerator Bed-Material Transfer System could begin, several system components had to be calibrated. The first components calibrated were the gasifier and regenerator weighbridges. A static-weight calibration for each weighbridge appears in Tables 4.1 and 4.2. The agreement between the display reading and actual weight using static weights is excellent. When a known weight of bed material was substituted for the static weights, however, an appreciable deviation between the true weight and the display reading was observed. It was evident that a considerable portion of the downward bed-material weight force was being counteracted by an upward frictional force of the bed material against the side walls of the gasifier and regenerator. To use the weighbridge system to measure a change in bed weight, fluidized calibrations of bed weight versus display reading were made. The data from these calibrations are presented in tabular form in Table 4.3 and graphically in Figures 4.1 through 4.3. These calibrations were performed in the following manner. A known weight of bed material was charged to the gasifier or regenerator and fluidized for several minutes. The bed was then defluidized and the display reading recorded. The bed was fluidized again and a known weight of bed material removed through the bed removal system. The beds were once again defluidized and the display reading again recorded. The true weight at this point was the previous true weight minus the amount of material removed. In this way a graph of display reading versus true weight was obtained.

Table 4.1 Gasifier Weighbridge Calibration Using Static Weights

No.	True Weight (lb)	Display Reading	True Weight Difference (I+1) - (I) (lb)	Display Reading Difference (I+1) - (I)	No.	True Weight (lb)	Display Reading	True Weight Difference (I+1) - (I) (lb)	Display Reading Difference (I+1) - (I)
1	0	0	80	81	14	1000	1003	162	163
2	80	81	80	81	15	1162	1166	185	185
3	160	162	80	80	16	1347	1351	191	192
4	240	242	80	80	17	1538	1543		
5	320	322	80	80	18*	1000	1006	46	46
6	400	402	80	80	19	1046	1052	39	40
7	480	482	80	81	20	1085	1092	79	80
8	560	563	80	80	21	1164	1172	73	73
9	640	643	80	80	22	1237	1245	185	186
10	720	723	80	80	23	1422	1431	165	162
11	800	803	80	80	24	1587	1593	191	192
12	880	883	80	80	25	1778	1785	259	260
13	960	963	40	40	26	2037	2045		

*Some weight removed.

Table 4.2 Regenerator Weighbridge Calibration
Using Static Weights

No.	True Weight (lb)	Display Reading	True Weight Difference (I+1) - (I) (lb)	Display Reading Difference (I+1) - (I)
1	2	1		
2	82	83	80	82
3	162	164	80	81
4	242	246	80	82
5	322	328(322)*	80	76
6	402	402	80	80
7	482	482	80	80
8	562	562	80	80
9	642	642	80	80
10	722	721	80	79
11	802	801	80	80
12	882	881	80	80
13	962	961	80	80
14	1002	1001(1002)*	40	41
15	1082	1083	80	81
16	1162	1163	80	80
17	1202	1203	40	40
18	1365	1366	163	163
19	1550	1550	185	184
20	1741	1742	191	192
21	1970	1970	229	228

*Span adjustment reset; use figure in parenthesis.

Table 4.2 Regenerator Weighbridge Calibration
Using Static Weights (Cont)

No.	True Weight (lb)	Display Reading	True Weight Difference (I+1) - (I) (lb)	Display Reading Difference (I+1) - (I)
<u>Unloading Weights</u>				
22	1203	1203	80	80
23	1123	1123	80	80
24	1043	1043	78	80
25	965	963	80	80
26	885	883	80	80
27	805	803	80	80
28	725	723	79	80
29	646	643	80	80
30	566	563	80	80
31	486	483	80	80
32	406	403	80	80
33	326	323	80	80
34	246	243	80	80
35	166	163	80	80
36	86	83	81	80
37	5	3		

Table 4.3 Fluidized Calibrations 1 and 2

Calibration 1			Calibration 2		
Bed Height (in.)	Display Reading	True Weight (lb)	Bed Height (in.)	Display Reading	True Weight (lb)
26	1185	2286	26	1174	2179
24	1181	2082	23	1151	1989
22	1139	1876	20	1117	1798
20	1074	1672	18	1061	1592
16	990	1468	16	960	1388
15	885	1265	14	873	1194
12	785	1061			
10	673	858			
9	590	656			

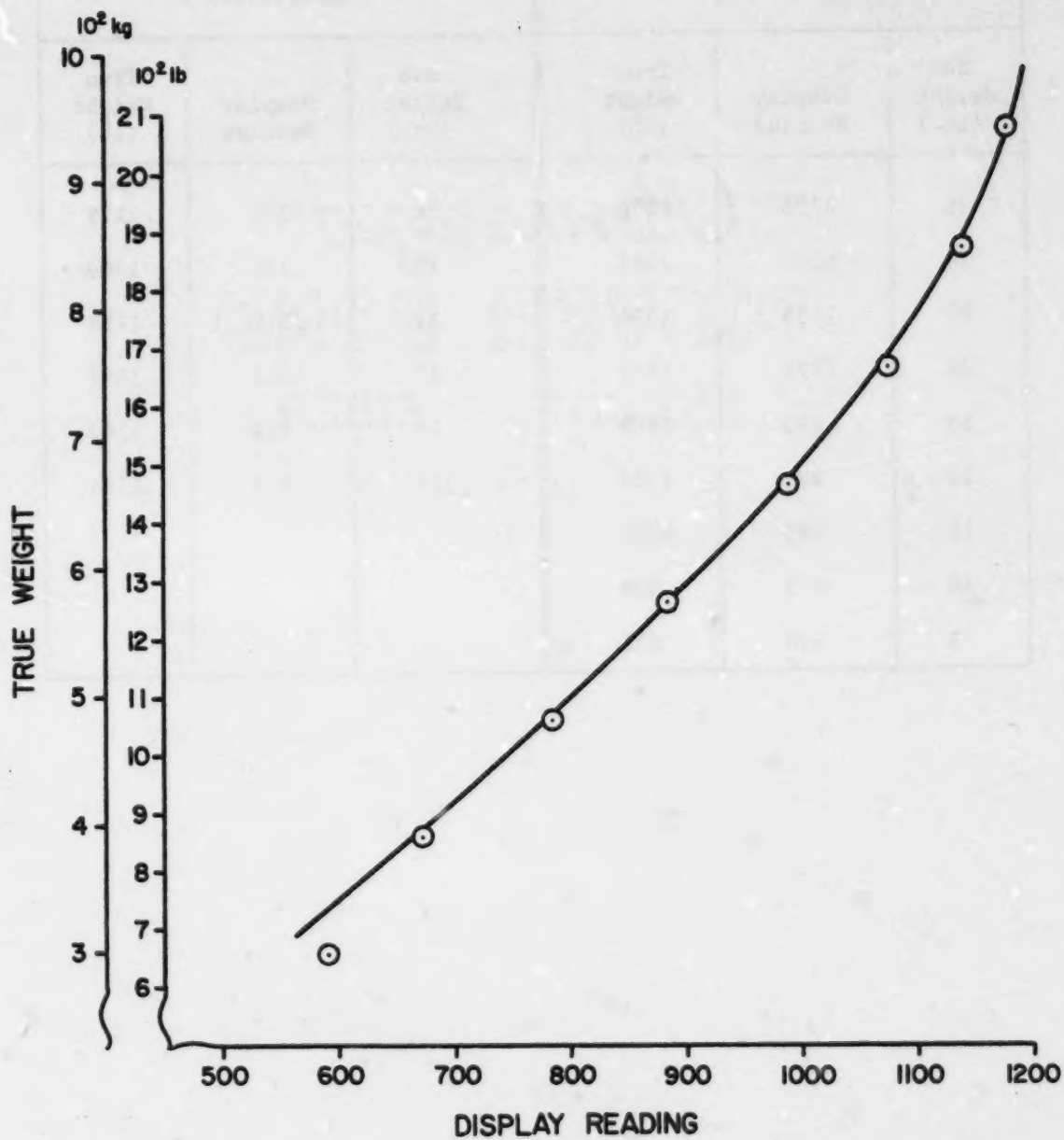


Figure 4.1 Fluidized Calibration 1

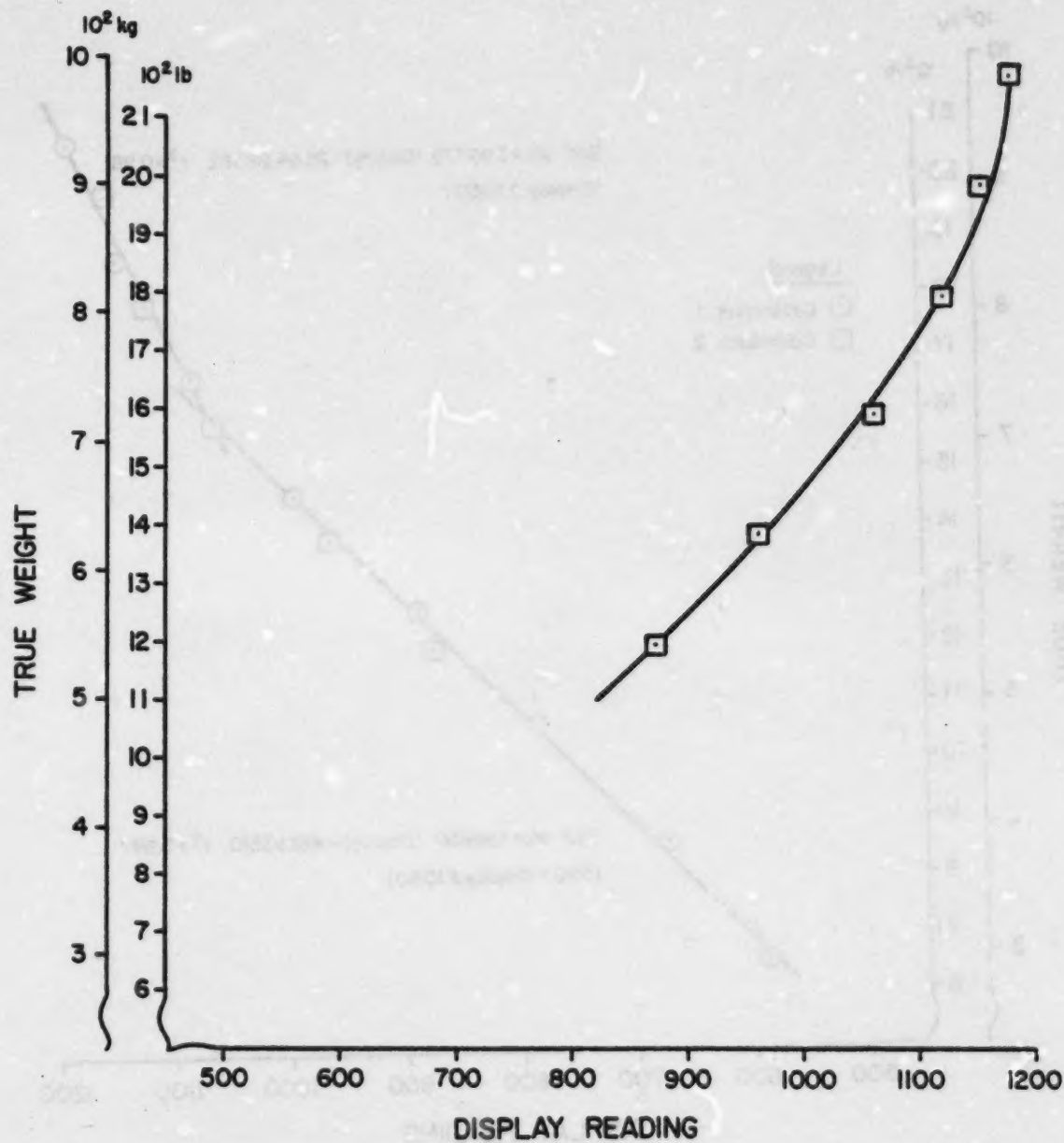


Figure 4.2 Fluidized Calibration 2

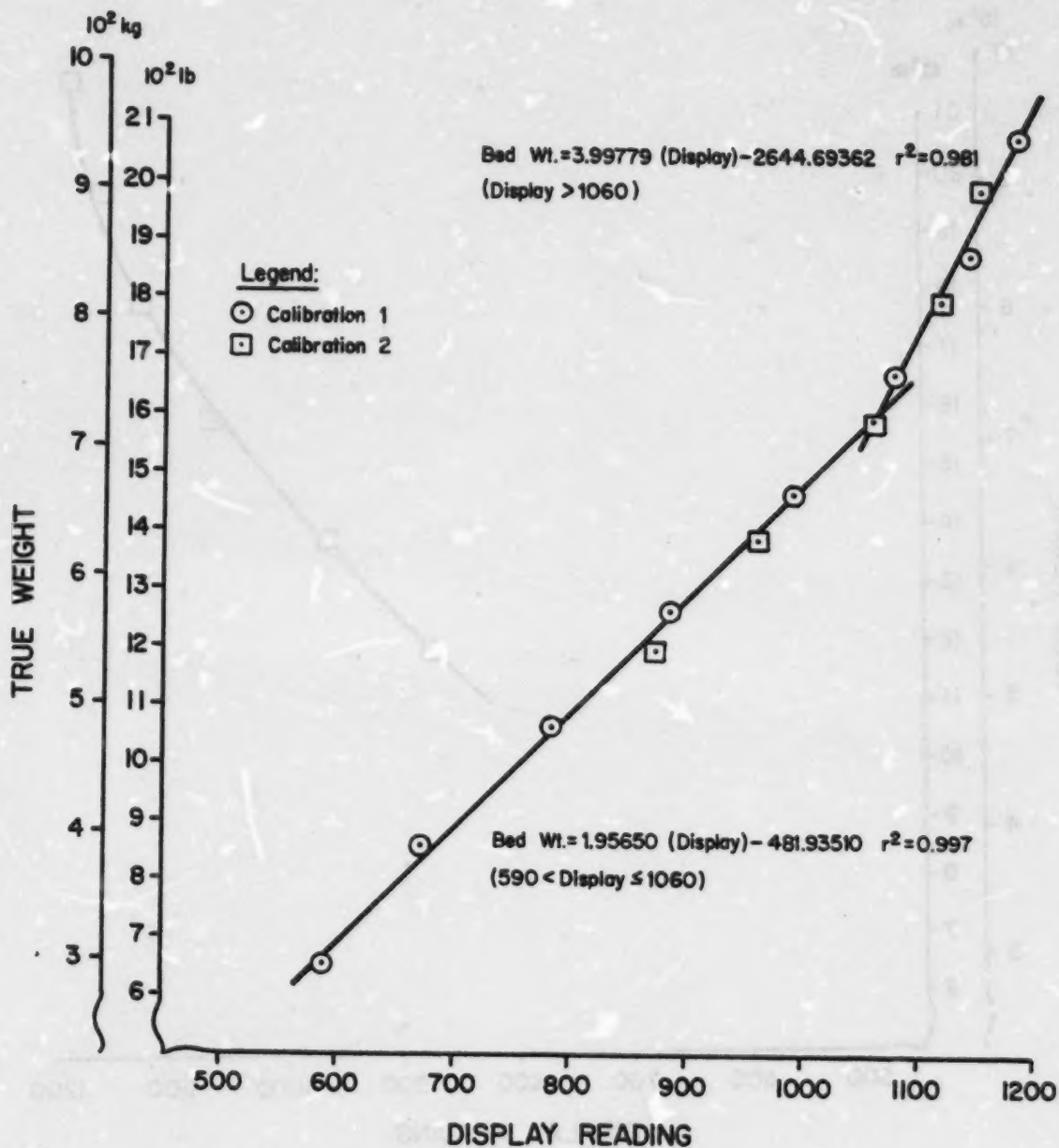


Figure 4.3 Combined Fluidized Calibrations 1 and 2

4.2.2 Timers

The four timers used to control the on or off times of the solenoid valves were calibrated in terms of timer setting versus actual time in seconds. A tabular presentation of these calibrations appears in Table 4.4. A graphical representation of these calibrations illustrating the variation in data appears in Figures 4.4 through 4.7.

4.3 PRELIMINARY TESTS

As illustrated in Section 3, the primary gasifier-regenerator bed-material transfer slot failed to transfer any bed material until the second-generation changes described in Section 3.2.3 were made. Data points were not recorded until the third generation of the primary gasifier-regenerator bed-material transfer slot (as shown in Figure 3.5) had been developed. As described in Section 3.2.4, for some tests bed material was transferred in only one direction for a short period of time and the bed-material transfer rate calculated from the change in bed weight (determined from display readings and the fluidized calibration curve) over the operating time period. As an additional confirmation of the transfer rate, the external recycle system was used to maintain constant bed levels. The agreement in bed-material transfer rate was acceptable.

In an effort to improve the efficiency of both material transfer rate and transport-air utilization, the system changes described in Section 3.2.5 were made. Data points were obtained for both the rectangular sparger which contained one hundred 9/32-in.-diameter holes and the rectangular sparger when the front face was replaced with a section of perforated plate. This slot design incorporating the perforated-plate sparger was designated Primary Gasifier-Regenerator Bed-Material Transfer System--Fourth Change and is illustrated in Figure 3.6.

The bed-material transfer rate using the perforated-plate sparger appeared to increase significantly over that obtained previously, as evidenced by a large increase in gasifier bed height even when the external recycle system was transferring material from the gasifier to the regenerator at the maximum rate of 4100 lb/h. Since previous tests had shown a marked bed-material transfer rate dependence on bed height in either bed, the efficiency of the external recycle system was improved to maintain essentially constant bed heights during bed-material transfer. Because the bed-material transfer rate was now determined by the external recycle system bed-material removal rate, with the bed levels in both gasifier and regenerator held essentially constant, the weighbridge system was no longer used to measure a change in weight per unit time. The weighbridges did, nevertheless, perform a useful function during data acquisition.

When the beds were slumped, the display indicated the weight of bed material (after reference to the calibration discussed earlier). As fluidizing air was admitted to the bed, the display value decreased and became negative.

Table 4.4 Calibrations for Transport-Air Pulse-Control Timers
(time in seconds)

Setting	Low Value	Calibration				High Value	Average*	Error (±)	% Error (±)
		1	2	3	4				
Timer (1) - ON									
0	1.0	---	---	---	1.9	2.3	1.65	0.65	39.4
1	4.0	4.9	4.6	4.6	4.8	5.1	4.55	0.55	12.1
2	5.5	6.1	6.2	6.0	6.2	6.7	6.10	0.60	9.8
3	7.7	8.4	8.2	8.1	8.1	9.0	8.35	0.65	7.8
4	9.9	10.0	10.2	10.3	10.5	11.2	10.55	0.65	6.2
5	12.4	12.8	12.6	12.7	13.0	13.6	13.00	0.60	4.6
6	14.9	15.0	14.8	15.0	15.4	16.0	15.45	0.55	3.6
7	17.3	17.4	17.3	17.2	17.7	18.4	17.85	0.55	3.1
8	19.5	20.0	20.0	19.9	20.1	21.3	20.40	0.90	4.4
9	21.7	21.8	21.9	21.7	22.0	23.0	22.35	0.65	2.9
10	24.9	24.9	24.0	24.7	26.0	27.2	26.05	1.15	4.4
Timer (2) - OFF									
0	1.3	---	---	---	2.0	2.4	1.85	0.55	29.7
1	3.9	4.0	4.5	4.3	4.6	4.9	4.40	0.50	11.4
2	5.8	5.8	6.1	6.0	6.2	6.8	6.30	0.50	7.9
3	8.0	8.4	8.4	8.3	8.5	9.6	8.80	0.80	9.1
4	10.8	10.6	10.9	10.6	11.0	11.7	11.25	0.45	4.0
5	13.1	12.7	12.8	12.8	13.2	13.8	13.45	0.35	2.6
6	14.5	14.2	14.4	14.3	14.7	15.2	14.85	0.35	2.4
7	16.0	16.0	16.0	15.9	16.6	17.1	16.55	0.55	3.3
8	18.5	18.6	18.3	18.1	18.8	19.5	19.00	0.50	2.6
9	19.9	20.1	19.7	19.7	20.4	21.7	20.80	0.90	4.3
10	24.9	24.6	24.1	24.3	26.0	26.9	25.90	1.00	3.9

* Average = $\frac{\text{low} + \text{high}}{2}$

Table 4.4 Calibrations for Transport-Air Pulse-Control Timers
(time in seconds) (Cont)

Setting	Low Value	Calibration				High Value	Average*	Error (±)	% Error (±)
		1	2	3	4				
Timer (3) - ON									
0	0.7	---	---	---	1.2	1.8	1.25	0.55	44.0
1	4.3	4.5	4.9	4.7	5.0	5.5	4.90	0.60	12.2
2	6.5	6.9	7.1	6.7	7.0	7.5	7.00	0.50	7.1
3	8.4	8.9	8.6	8.8	8.8	9.5	8.95	0.55	6.1
4	10.7	10.9	10.8	10.6	11.0	11.8	11.25	0.55	4.9
5	12.9	12.8	13.0	12.8	13.3	13.7	13.30	0.40	3.0
6	14.6	15.0	14.9	15.0	15.5	15.9	15.25	0.65	4.3
7	17.0	17.4	17.0	16.8	17.6	18.5	17.75	0.75	4.2
8	19.3	19.9	19.6	19.1	19.8	20.5	19.90	0.60	3.0
9	21.2	21.5	21.3	20.8	21.5	22.3	21.75	0.55	2.5
10	25.0	24.9	24.0	24.5	25.8	26.8	25.90	0.90	3.5
Timer (4) - OFF									
0	0.5	---	---	---	1.0	1.8	1.15	0.65	56.5
1	3.5	3.8	4.0	4.0	3.8	4.4	3.95	0.45	11.4
2	5.1	5.0	5.5	5.3	5.6	5.8	5.45	0.35	6.4
3	7.0	7.3	7.6	7.2	7.6	8.1	7.55	0.55	7.3
4	9.4	9.7	9.8	9.4	9.8	10.5	9.95	0.55	5.5
5	11.5	11.6	11.4	11.5	11.9	12.5	12.00	0.50	4.2
6	13.5	13.7	13.3	13.9	13.9	14.6	14.05	0.55	3.9
7	15.5	15.8	15.7	15.6	16.1	16.8	16.15	0.65	4.0
8	17.7	18.5	18.1	17.9	18.2	18.7	18.20	0.50	2.7
9	19.4	20.0	19.7	19.8	19.9	20.7	20.05	0.65	3.2
10	23.3	23.5	23.5	23.7	24.5	25.5	24.40	1.10	4.5

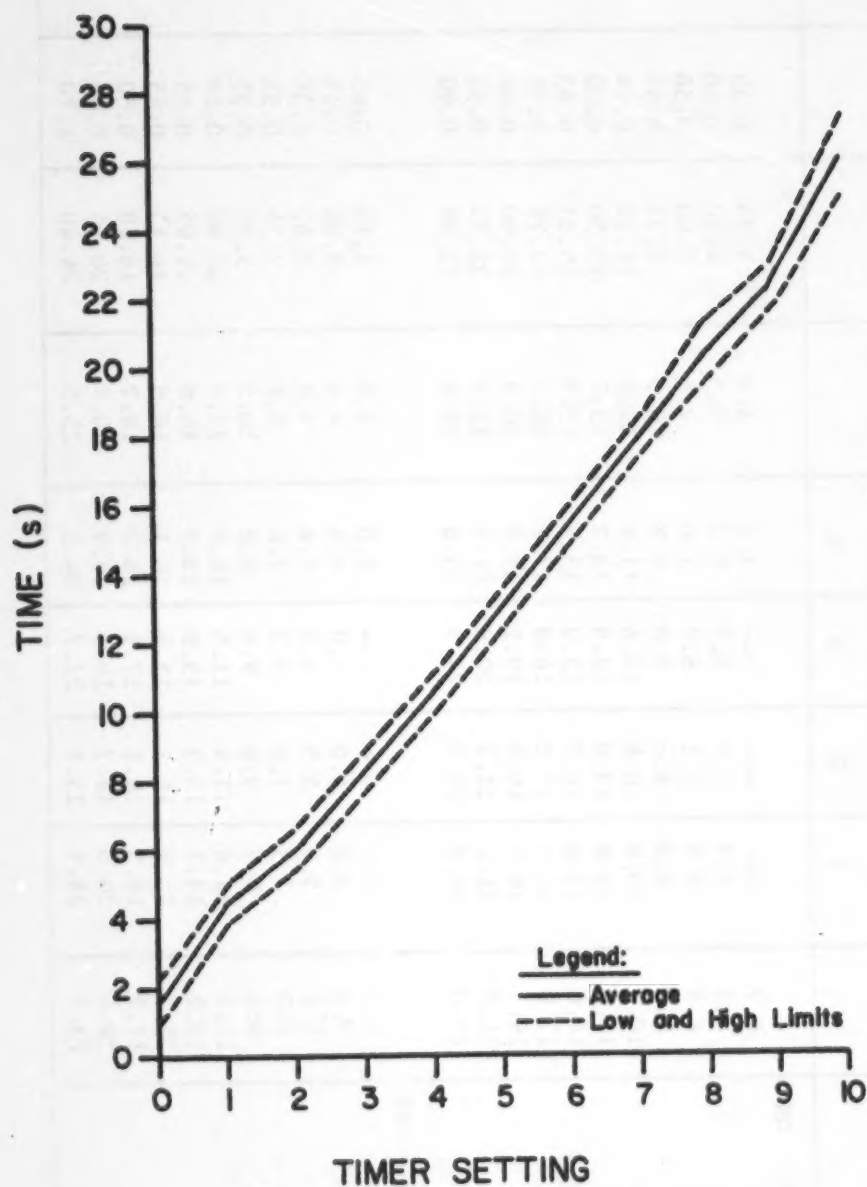


Figure 4.4 Calibration for Transport-Air Pulse-Control Timer 1

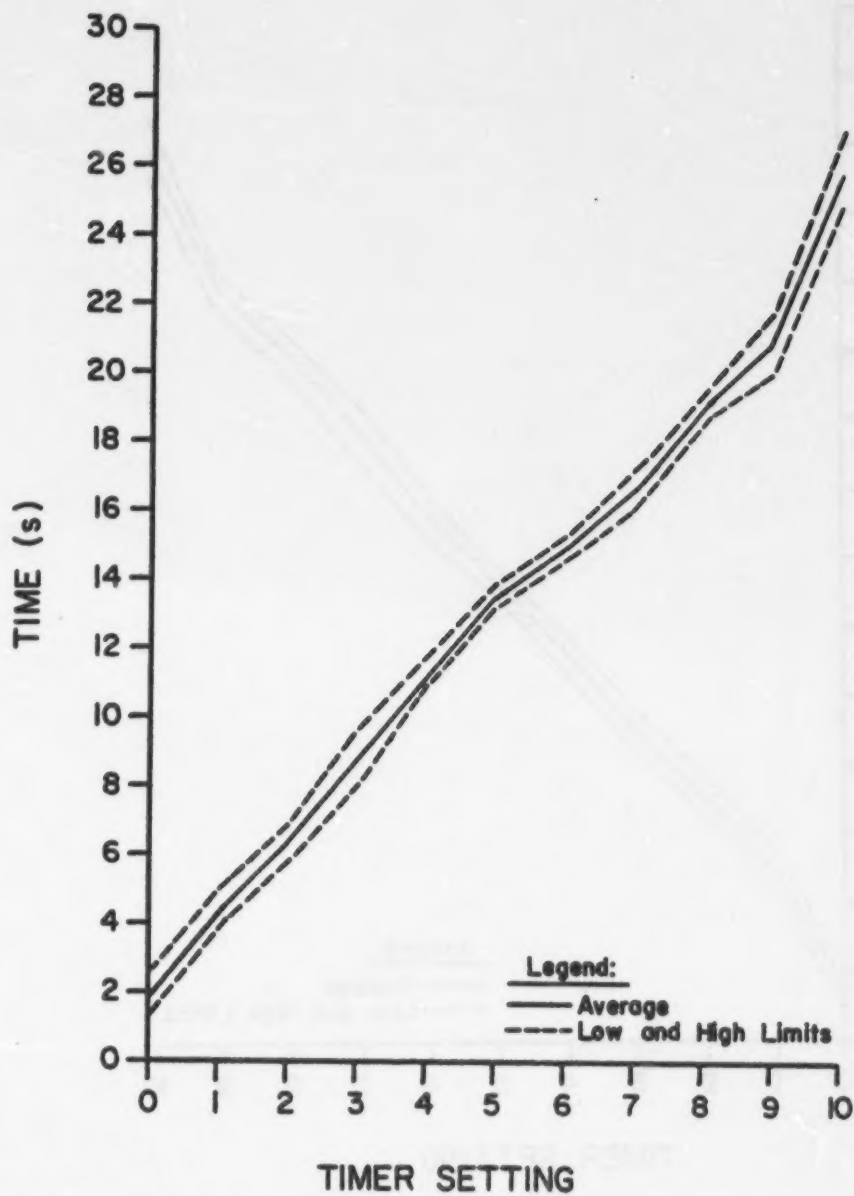


Figure 4.5 Calibration for Transport-Air Pulse-Control Timer 2

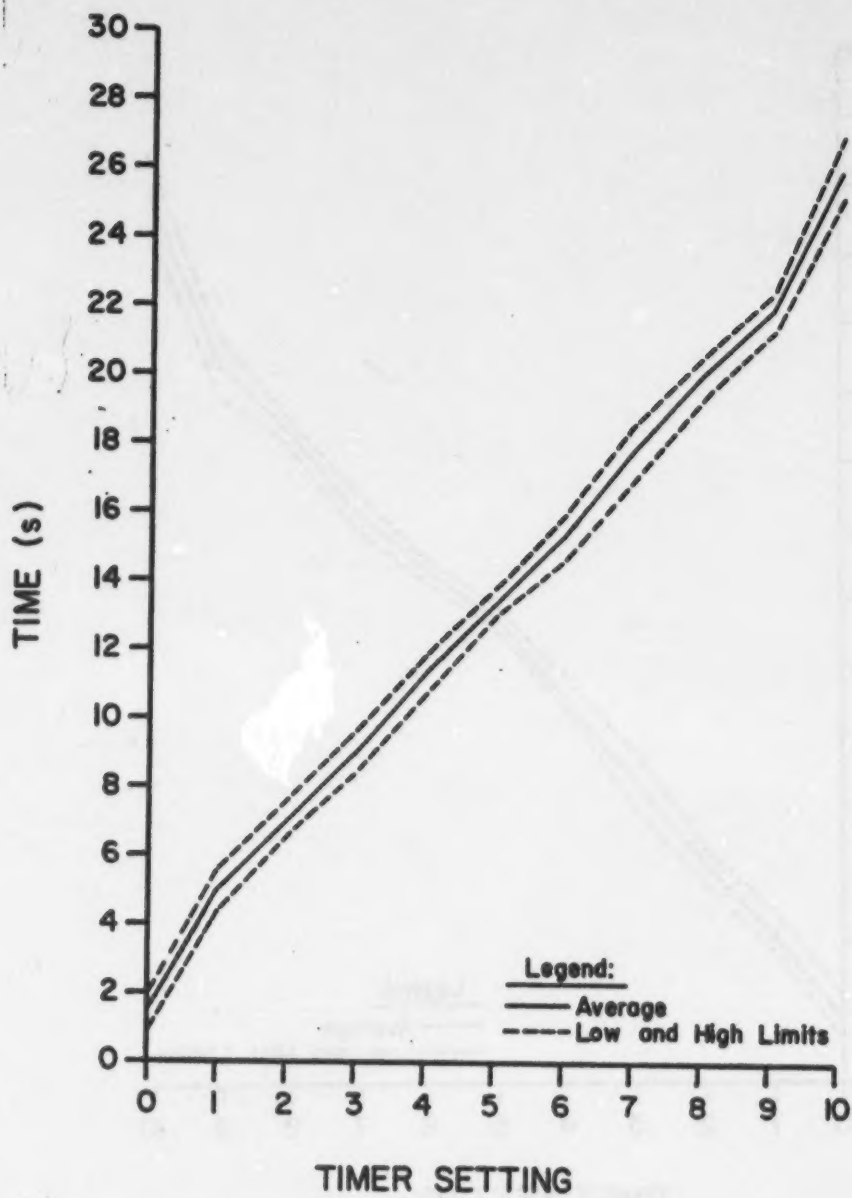


Figure 4.6 Calibration for Transport-Air Pulse-Control Timer 3

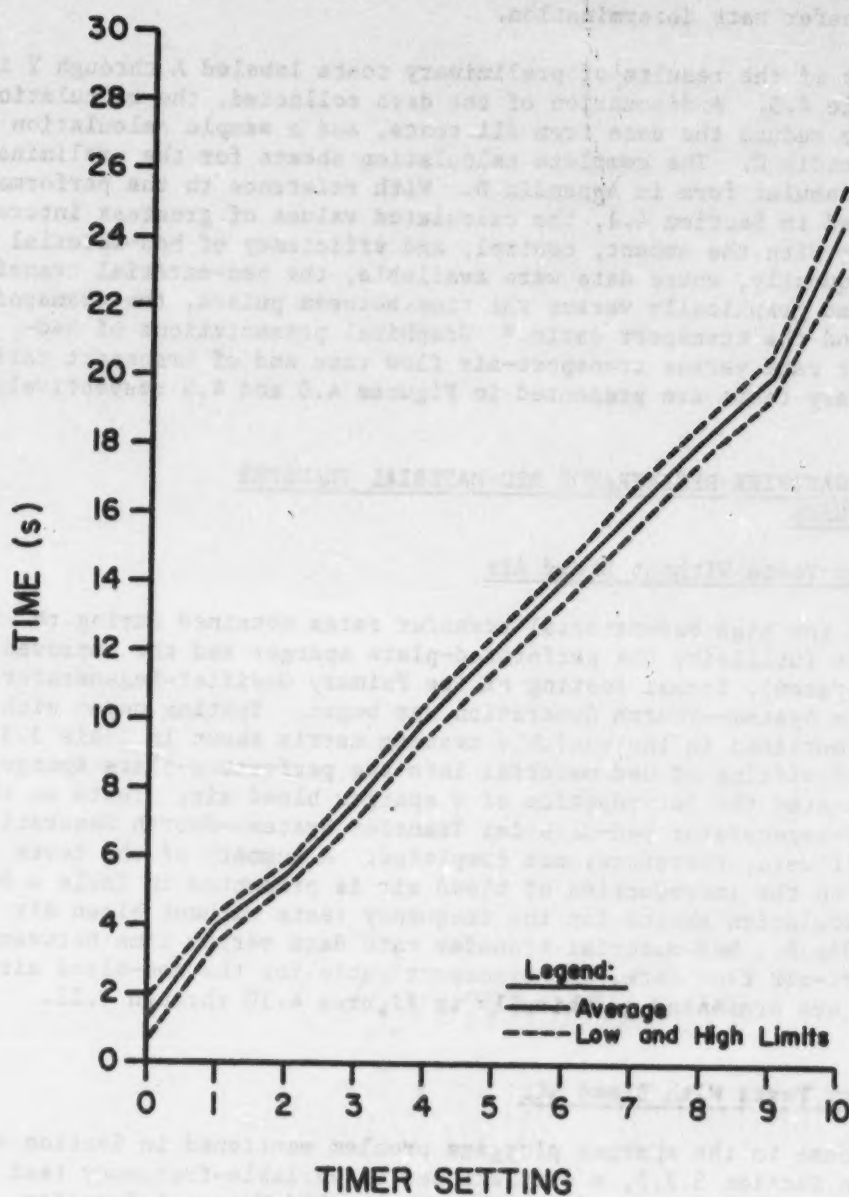


Figure 4.7 Calibration for Transport-Air Pulse-Control Timer 4

It was discovered that if approximately the same negative number was maintained in the display for both fluidized beds, the bed levels remained essentially constant. The negative displays provided a means of maintaining an approximately constant and equal bed height in both gasifier and regenerator during a test, resulting in the virtual elimination of the bed-height effect from the bed-material transfer rate determination.

A summary of the results of preliminary tests labeled A through Y is presented in Table 4.5. A discussion of the data collected, the calculation procedure used to reduce the data from all tests, and a sample calculation are presented in Appendix C. The complete calculation sheets for the preliminary tests appear in tabular form in Appendix D. With reference to the performance criteria presented in Section 4.1, the calculated values of greatest interest are those dealing with the amount, control, and efficiency of bed-material transfer. Consequently, where data were available, the bed-material transfer rate was presented graphically versus the time between pulses, the transport-air flow rate, and the transport ratio.* Graphical presentations of bed-material transfer rate versus transport-air flow rate and of transport ratio for the preliminary tests are presented in Figures 4.8 and 4.9 respectively.

4.4 PRIMARY GASIFIER-REGENERATOR BED-MATERIAL TRANSFER SYSTEM TESTS

4.4.1 Frequency Tests Without Bleed Air

Based on the high bed-material transfer rates obtained during the final preliminary tests (utilizing the perforated-plate sparger and the improved external recycle system), formal testing of the Primary Gasifier-Regenerator Bed-Material Transfer System--Fourth Generation was begun. Testing began with the frequency tests outlined in the variable testing matrix shown in Table 3.3. Considerable back-sifting of bed material into the perforated-plate sparger, however, necessitated the introduction of a sparger bleed air. Tests on the Primary Gasifier-Regenerator Bed-Material Transfer System--Fourth Generation without bleed air were, therefore, not completed. A summary of the tests performed prior to the introduction of bleed air is presented in Table 4.6. The complete calculation sheets for the frequency tests without bleed air appear in Appendix E. Bed-material transfer rate data versus time between pulses, transport-air flow rate, and transport ratio for the non-bleed air frequency tests are presented graphically in Figures 4.10 through 4.12.

4.4.2 Frequency Tests With Bleed Air

In response to the sparger pluggage problem mentioned in Section 4.4.1 and described in Section 3.2.5, a complete set of variable-frequency test data was generated for the Primary Gasifier-Regenerator Bed-Material Transfer System--Fourth Generation after the sparger bleed air was introduced. As

*The transport ratio is defined as equal to the amount of bed material transferred by 1 sft³ of activating gas (standard conditions are 14.7 lb/in²a and 70°F).

Table 4.5 Summary of Results of the Primary Gasifier-Regenerator Bed-Material Transfer Slot--Third and Fourth Generations--Preliminary Tests

Test	Air Flow Rate (lb/min)	Sparger Pressure (lb/in ² g)	Pulse Time (s)		Air Flow Rate* (scf ³ /min)	Bed-Material Transfer Rate (lb/h)	Transport Ratio (lb/scf ³ air)	Operating Time (min)	Comments
			On	Off					
50-Hole Sparger:									
A	4.73	6	---	---	63.19	4,104	1.08	15	Recycle on
B	4.88	6	---	---	65.16	2,730	0.70	10	Recycle off
C	3.88	---	---	---	51.84	4,104	1.32	10	Recycle on
D†	4.33	---	---	---	57.76	3,534	1.02	10	Recycle off
E†	4.44	---	---	---	59.24	2,928	0.82	5	Recycle off
F	13.59	---	---	---	181.42	7,575	0.70	4	Recycle off
G	5.43	---	---	---	72.57	5,040	1.16	10	Recycle on
H	10.35	---	---	---	138.23	9,594	1.16	6	---
100-Hole Sparger:									
I	8.87	---	---	---	118.48	16,044	2.26	5	Recycle on
J‡	8.87‡	5	---	---	118.48‡	5,192	0.73	15	Recycle on‡
K	8.43	---	---	---	112.56	10,560	1.56	5	Recycle on
L‡	8.43‡	---	---	---	112.56‡	6,588	0.98	15	Recycle on‡
M	7.52	---	---	---	100.38	9,444	1.57	9	Recycle on
Perforated-Plate Sparger:									
N	7.61	---	---	---	101.55	8,789	1.44	7	Pipe recycle
O‡	7.61‡	---	---	---	101.55‡	14,935	2.45	5.31	Questionable‡
P	6.14	---	---	---	82.02	20,114	4.09	6.5	Improved recycle
Q	9.10	≈6	---	---	121.54	17,212	2.36	8.65	Improved recycle‡
R	9.10	6.5	---	---	121.50	16,242	2.23	9.14	Improved recycle‡
S	11.65	6.5	---	---	155.51	14,863	1.59	7	Improved recycle‡
T	13.10	6.5	---	---	174.92	20,027	1.91	6.35	Improved recycle‡
U	8.88	7	1.25	1.15	118.56	26,629	3.74	9.87	Improved recycle
V	9.65	6.5	1.25	1.15	128.82	26,044	3.37	8.45	Improved recycle
W	7.19	7.3	---	---	96.03	22,475	3.90	11.57	Improved recycle
X	7.59	7.3	---	---	101.32	22,989	3.78	10.82	Improved recycle
Y‡	7.59‡	---	---	---	101.32‡	22,072	3.63	30	Improved recycle‡

*Standard conditions are 14.7 lb/in²a and 70°F.

₄Plugged.

₅Compressor running.

₄Assumed to be the same as a previous run.

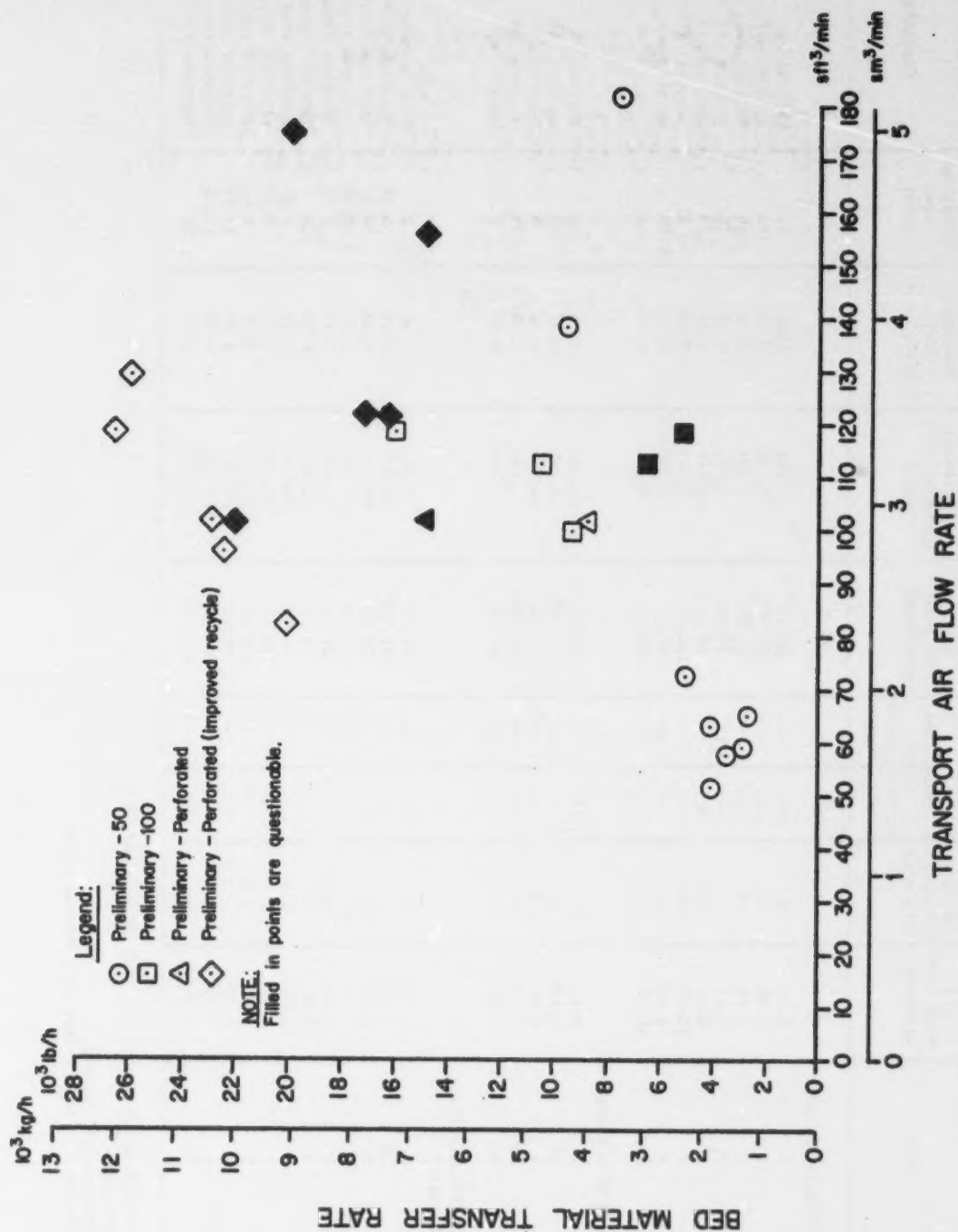


Figure 4.8 Primary Gasifier-Regenerator Bed-Material Transfer Slot--Third and Fourth Generations-- Preliminary Tests--Bed-Material Transfer Rate vs. Transport-Air Flow Rate

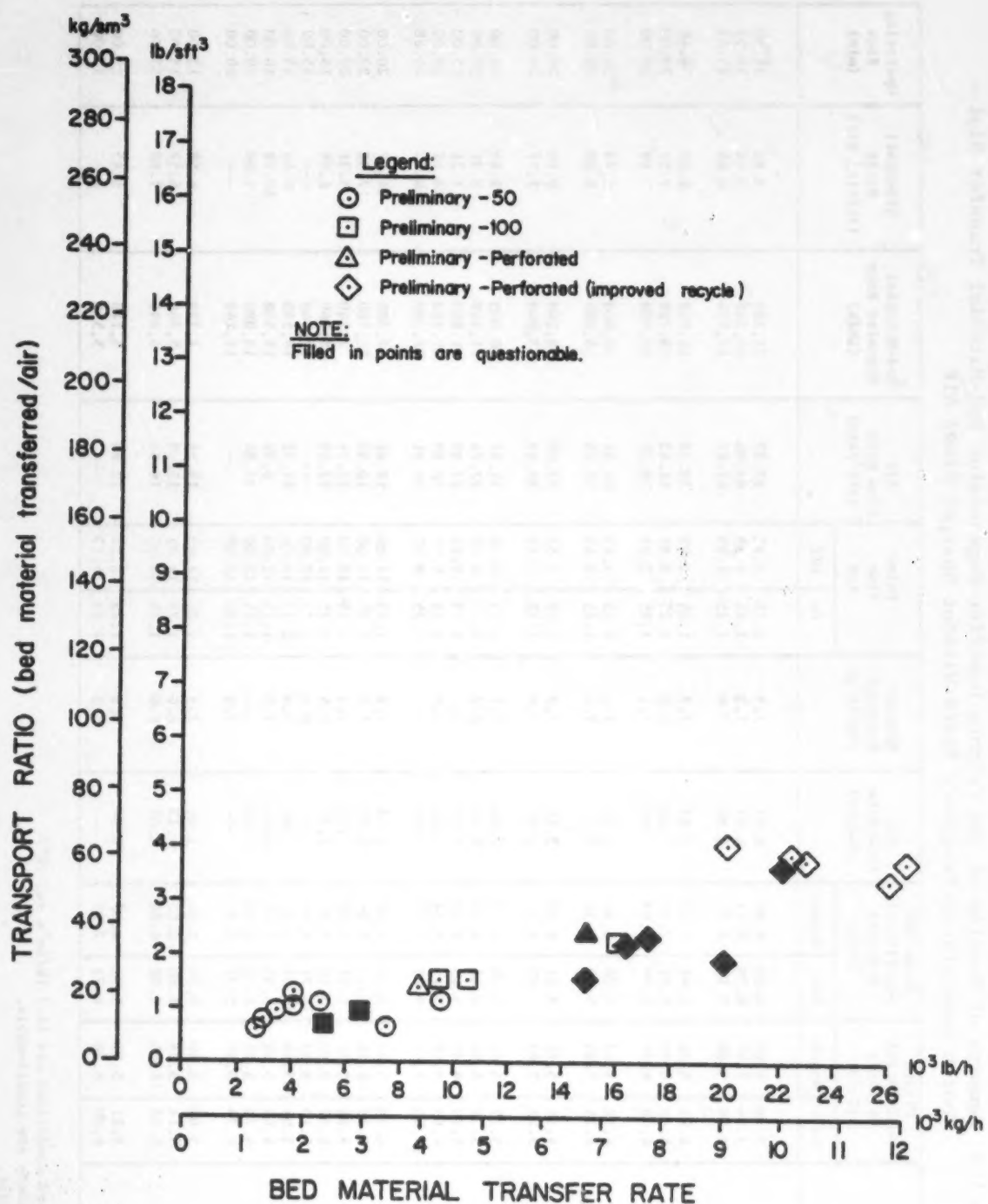


Figure 4.9 Primary Gasifier-Regenerator Bed-Material Transfer Slot--Third and Fourth Generations--Preliminary Tests--Transport Ratio vs. Bed-Material Transfer Rate

Table 4.6 Summary of Results of the Primary Gasifier-Regenerator Bed-Material Transfer Slot---
Fourth Generation---Frequency Tests Without Sparger Bleed Air

Test No.	Plenum Superficial Velocity (ft/s)		Above-Bed Superficial Velocity (ft/s)		Air Flow Rate (lb/min)	Sparger Pressure (lb/in ² g)	Pulse Time (s)		Air Flow Rate (scf ³ /min)	Bed-Material Transfer Rate (lb/h)	Transport Ratio (lb/scf ³ air)	Operating Time (min)
	Gas.	Regen.	Gas.	Regen.			On	Off				
F0	5.36	6.05	6.05	6.84	6.91	7.5	1.25	1.15	92.27	21,120	3.81	11.50
F0R ₁	5.94	7.92	6.79	9.11	4.87	7.0	1.25	1.15	65.06	21,240	5.44	16.53
F0R ₂	4.56	5.80	5.15	6.55	5.08	7.0	1.25	1.15	67.87	18,920	4.65	15.47
F1	4.82	6.31	5.44	7.12	2.87	7.2	1.25	3.95	38.38	14,940	6.49	6.46
F1R ₁	4.40	6.26	4.97	7.07	3.10	7.0	1.25	3.95	41.43	18,720	7.53	20.00
F1R ₂	4.48	6.26	5.06	7.07	2.98	7.1	1.25	3.95	39.76	18,800	7.88	20.00
F2	4.58	5.67	5.20	6.44	3.71	7.0	1.25	5.45	49.61	20,040	6.73	20.00
F2R ₁	4.75	5.84	5.33	6.56	2.34	7.0	1.25	5.45	31.25	18,000	9.60	20.00
F3	4.64	5.71	5.21	6.40	2.48	7.0	1.25	7.55	33.07	18,160	9.15	20.00
F3R ₁	5.21	5.65	5.85	6.34	2.99	7.0	1.25	7.55	39.89	18,840	7.87	20.00
F4	5.12	5.95	5.79	6.72	2.39	7.1	1.25	9.95	31.91	18,000	9.40	20.00
F4R ₁	5.39	5.94	6.08	6.70	1.70	8.0	1.25	9.95	22.74	11,340	8.31	20.00
F4R ₂ †	5.20	6.30	5.85	7.10	2.05	7.5	1.25	9.95	27.39	11,850	7.21	15.00
F4R ₃ †	4.63	5.68	5.17	6.34	1.54	7.0	1.25	9.95	20.50	17,120	13.92	20.00
F4R ₄	4.56	5.67	5.08	6.32	2.02	---	1.25	9.95	26.91	17,160	10.63	10.88
F5	4.70	5.97	5.28	6.70	1.48	7.0	1.25	12.00	19.81	17,200	14.47	20.00
F5R ₁	5.39	6.16	6.09	6.96	0.82	7.0	1.25	12.00	10.90	11,760	17.98	20.00
F5R ₂	4.64	5.81	5.24	6.56	1.70	9.0	1.25	12.00	22.74	7,240	5.31	20.00
F5R ₃	4.52	5.65	5.14	6.42	1.72	8.5	1.25	12.00	22.99	8,360	6.06	15.00
F5R ₄	5.12	5.82	5.72	6.49	---	8.0	1.25	12.00	---	12,040	---	15.00
F5R ₅	5.06	5.60	5.72	6.32	1.61	8.0	1.25	12.00	21.52	10,530	8.16	15.00
F5R ₆ ‡	4.69	5.89	5.33	6.69	0.51	7.0	1.25	12.00	6.79	12,540	30.79	16.00
F5R ₇	4.20	4.51	4.65	4.99	2.40	---	1.25	12.00	32.04	13,080	6.80	20.00
F5R ₈	4.79	5.86	5.37	6.57	---	7.0	1.25	12.00	---	12,240	---	20.00
F6	5.09	5.90	5.74	6.66	1.46	7.5	1.25	14.05	19.56	7,720	6.58	15.00
F6R ₁	5.14	5.86	5.80	6.62	1.13	8.0	1.25	14.05	15.08	5,940	6.57	15.00
F6R ₂	5.38	6.06	6.08	6.84	1.09	8.0	1.25	14.05	14.54	6,696	7.68	15.00
F7	5.27	5.81	5.91	6.52	0.94	8.0	1.25	16.15	12.60	4,120	5.45	15.00
F7R ₁	6.00	6.26	6.73	7.03	---	8.0	1.25	16.15	---	5,550	---	15.00

‡Standard conditions are 14.7 lb/in² and 70°F.

†Air values are questionable.

‡Bed point.

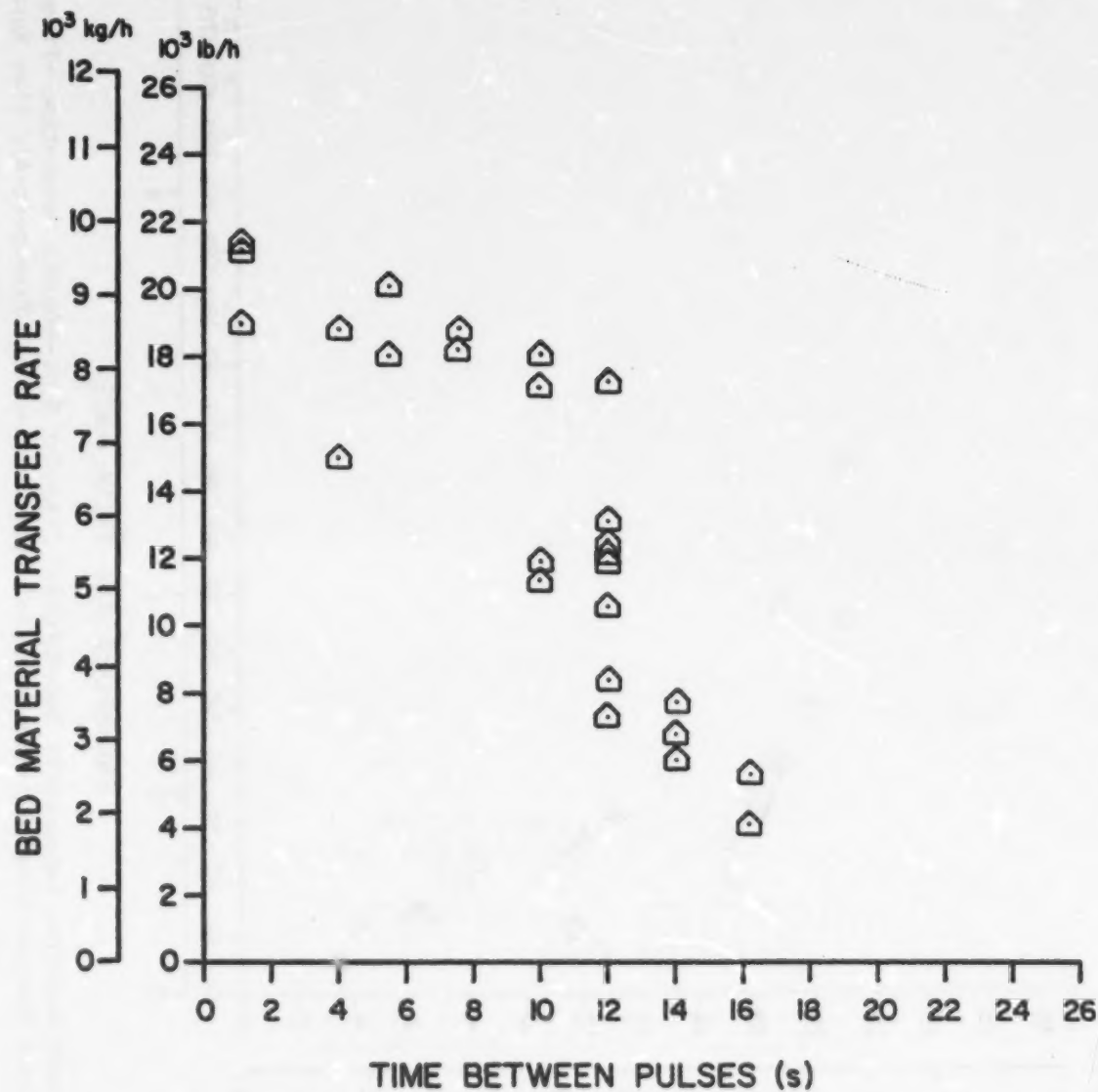


Figure 4.10 Primary Gasifier-Regenerator Bed-Material Transfer Slot--Fourth Generation--Frequency Tests Without Sparger Bleed Air--Bed-Material Transfer Rate vs. Time Between Pulses

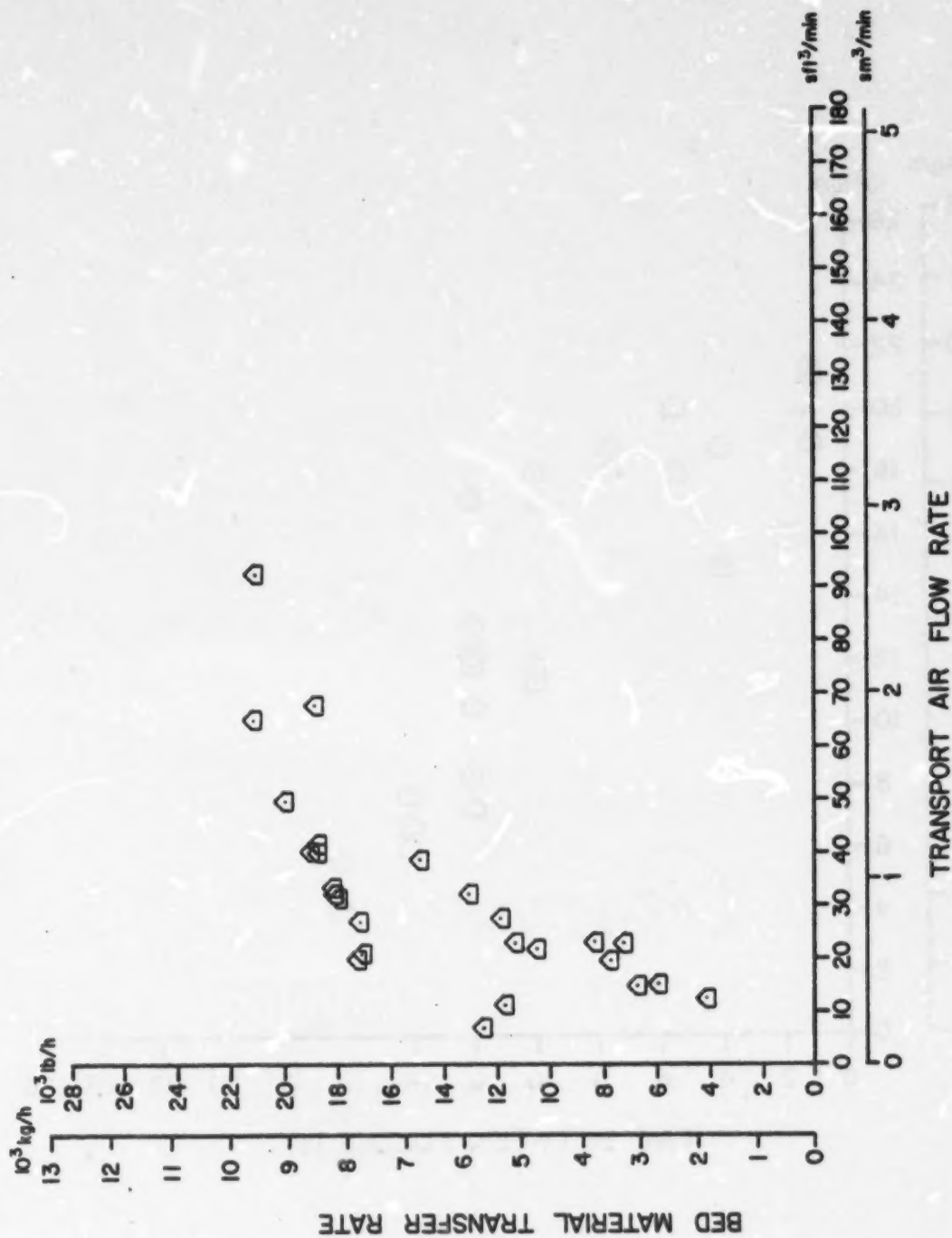


Figure 4.11 Primary Gasifier-Regenerator Bed-Material Transfer Slot--Fourth Generation--Frequency Tests Without Sparger Bleed Air--Bed-Material Transfer Rate vs. Transport-Air Flow Rate

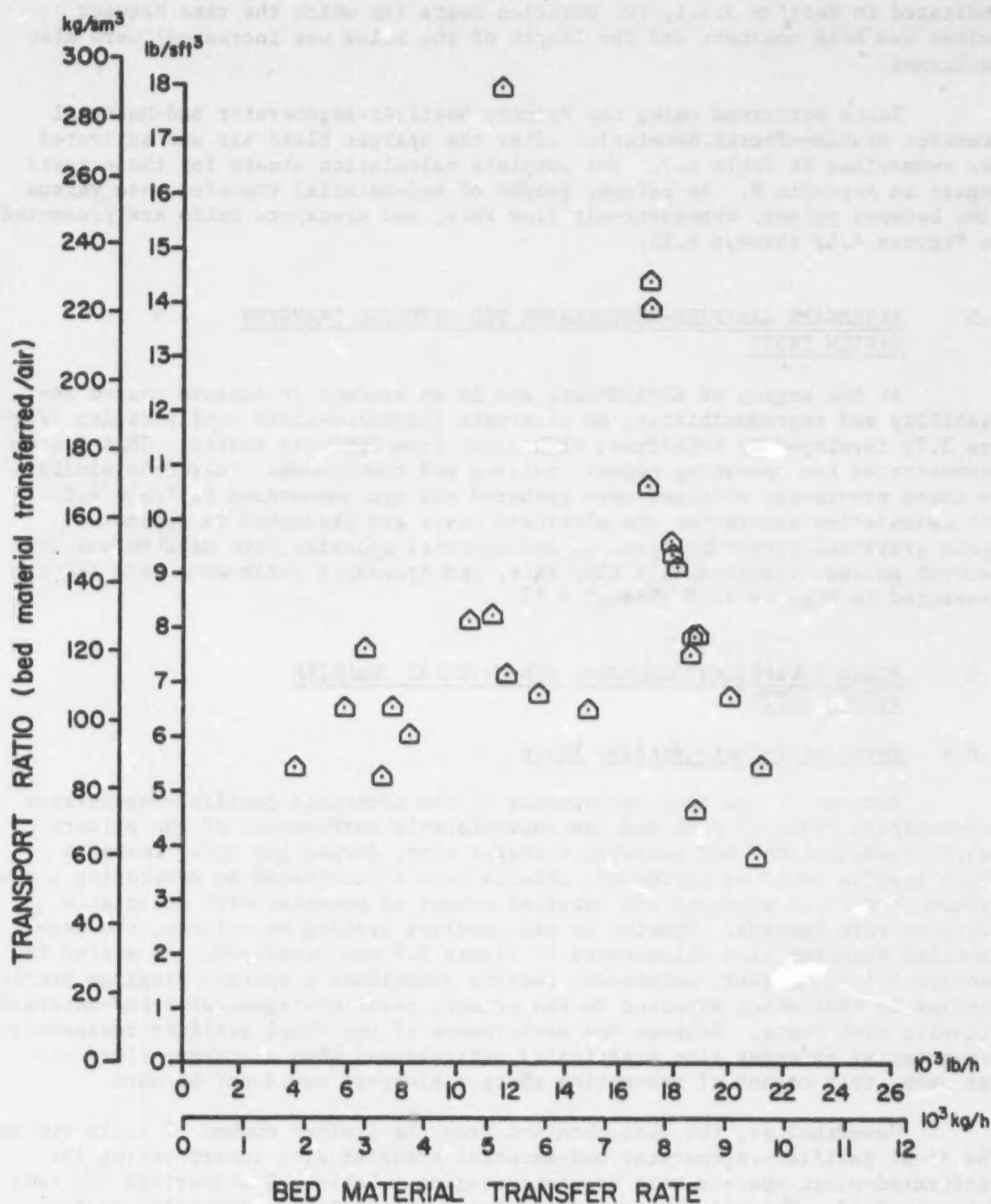


Figure 4.12 Primary Gasifier-Regenerator Bed-Material Transfer Slot--Fourth Generation--Frequency Tests Without Sparger Bleed Air--Transport Ratio vs. Bed-Material Transfer Rate

indicated in Section 3.3.1, two duration tests (in which the time between pulses was held constant and the length of the pulse was increased) were also performed.

Tests performed using the Primary Gasifier-Regenerator Bed-Material Transfer System--Fourth Generation after the sparger bleed air was activated are summarized in Table 4.7. The complete calculation sheets for these tests appear in Appendix F. As before, graphs of bed-material transfer rate versus time between pulses, transport-air flow rate, and transport ratio are presented in Figures 4.13 through 4.15.

4.5 ALTERNATE GASIFIER-REGENERATOR BED-MATERIAL TRANSFER SYSTEM TESTS

At the urging of ERCA/Exxon, and in an attempt to improve system reliability and reproducibility, an alternate (circular-slot) configuration (Figure 3.7) developed by ERCA/Exxon with input from FWEC was tested. This system demonstrated two operating modes: pulsing and continuous. Test data similar to those previously obtained were gathered and are summarized in Table 4.8. The calculation sheets for the alternate tests are presented in Appendix G. Again graphical representations of bed-material transfer rate data versus time between pulses, transport-air flow rate, and transport ratio were made and are presented in Figures 4.16 through 4.18.

4.6 FINAL GASIFIER-REGENERATOR BED-MATERIAL TRANSFER SYSTEM TESTS

4.6.1 Perforated-Plate Sparger Tests

Because of the poor performance of the alternate gasifier-regenerator bed-material transfer slot and the unpredictable performance of the primary gasifier-regenerator bed-material transfer slot, during the final weeks in which testing could be performed, efforts were concentrated on developing a new system that would transfer the required amount of material with acceptable transfer rate control. Drawing on all previous testing experience, the bed-material transfer slot illustrated in Figure 3.9 was developed. As stated in Section 3.4.1, however, subsequent testing pinpointed a sparger pluggage problem similar to that which appeared in the primary gasifier-regenerator bed-material transfer slot tests. Because the performance of the final gasifier-regenerator bed-material transfer slot drastically deteriorated when a sparger bleed air was used, this method of preventing sparger pluggage could not be used.

Nevertheless, the data obtained from the limited number of tests run on the final gasifier-regenerator bed-material transfer slot incorporating the perforated-plate sparger were very encouraging. Table 4.9 summarizes the test data obtained. The calculation sheets for these tests are presented in Appendix H. To show the control, amount, and efficiency of bed-material transfer, graphs of bed-material transfer rate versus time between pulses, transport-air flow rate, and transport ratio were once again drawn. These graphs are presented as Figures 4.19 through 4.21.

Table 4.7 Summary of Results of the Primary Gasifier-Regenerator Bed-Material Transfer Slot--Fourth Generation--Frequency and Duration Tests With Sparger Bleed Air

Test No.	Plenum Superficial Velocity (ft/s)		Above-Bed Superficial Velocity (ft/s)		Air Flow Rate (lb/min)	Sparger Pressure (lb/in ² g)	Pulse Time (s)		Air Flow Rate (scf ³ /min)	Bed-Material Transfer Rate (lb/h)	Transport Ratio (lb/scf ³ air)	Operating Time (min)
	Gas.	Regen.	Gas.	Regen.			On	Off				
F0(A)	5.14	5.80	5.74	6.47	10.09	6.5	1.25	1.15	134.74	21,600	2.67	4.4
F3/4(A)	5.01	5.37	5.57	5.96	6.55	6.5	1.25	3.00	87.47	19,680	3.75	2.1
F1(A)	5.54	6.49	6.22	7.28	6.00	6.5	1.25	3.95	80.10	21,840	4.54	1.6
F1R ₁ (A)	5.60	6.99	6.29	7.85	9.98	6.5	1.25	3.95	133.27	22,320	2.79	1.1
F2(A)	4.98	5.31	5.55	5.92	---	---	1.25	5.45	---	22,230	---	12.5
F2R ₁ (A)	5.35	6.47	6.00	7.26	---	7.0	1.25	5.45	---	22,290	---	15.0
F2R ₂ (A)	5.90	6.59	6.66	7.44	4.48	7.2	1.25	5.45	59.86	23,190	6.46	15.0
F3(A)	5.26	6.17	5.90	6.93	3.20	7.0	1.25	7.55	42.70	19,240	7.51	16.0
F3R ₁ (A)	4.70	5.81	5.28	6.52	3.81	7.0	1.25	7.55	50.89	19,320	6.33	15.0
F4(A)	5.27	5.96	5.92	6.69	3.70	7.0	1.25	9.95	49.42	14,160	4.78	15.0
F4R ₁ (A)	5.82	6.26	6.54	7.02	---	7.0	1.25	9.95	---	13,248	---	15.0
F4R ₂ (A)	5.74	5.99	6.45	6.72	---	7.0	1.25	9.95	---	13,840	---	23.0
F5(A)	5.67	6.76	6.37	7.58	2.77	7.0	1.25	12.00	36.97	12,480	5.63	17.0
F5R ₁ (A)	5.24	6.05	5.88	6.79	2.61	7.0	1.25	12.00	34.89	12,840	6.13	15.0
F6(A)	5.31	6.39	5.96	7.17	2.41	6.5	1.25	14.05	32.19	9,400	4.87	17.0
F6R ₁ (A)	4.81	6.35	5.39	7.13	2.44	6.5	1.25	14.05	32.65	8,000	4.08	15.0
F7(A)	4.74	5.85	5.29	6.53	1.86	6.5	1.25	16.15	24.90	8,580	5.74	15.0
F7R ₁ (A)	4.95	6.28	5.55	7.04	2.12	6.5	1.25	16.15	28.26	8,430	4.97	15.0
F7R ₂ (A)	5.40	6.52	6.09	7.37	2.09	6.5	1.25	16.15	27.84	6,520	3.90	15.0
F8(A)	6.39	5.85	7.21	6.61	1.94	7.0	1.25	18.20	25.88	6,885	4.43	15.0
F8R ₁ (A)	6.46	5.91	7.30	6.67	1.79	7.0	1.25	18.20	23.96	7,560	5.26	15.0
F9(A)	5.44	6.67	6.11	7.49	2.02	7.0	1.25	20.05	26.96	6,480	4.01	16.0
F9R ₁ (A)	4.78	6.02	5.37	6.75	1.94	6.75	1.25	20.05	25.88	6,765	4.36	15.0
F10(A)	5.64	6.54	6.06	7.03	1.91	6.75	1.25	24.40	25.46	6,240	4.08	17.0
F10R ₁ (A)	5.17	6.51	5.80	7.31	2.02	6.75	1.25	24.40	26.93	6,675	4.13	15.0
F10R ₂ (A)	5.33	6.43	5.98	7.21	2.04	6.50	1.25	24.40	27.25	5,200	3.18	16.0
D0(A)	5.70	6.46	6.36	7.20	4.26	7.0	1.25	5.45	56.90	11,730	3.44	1.3
D2(A)	5.65	6.37	6.30	7.11	3.74	7.0	7.0	5.45	49.98	4,320	1.44	5.0

*Standard conditions are 14.7 lb/in² a and 70°F.

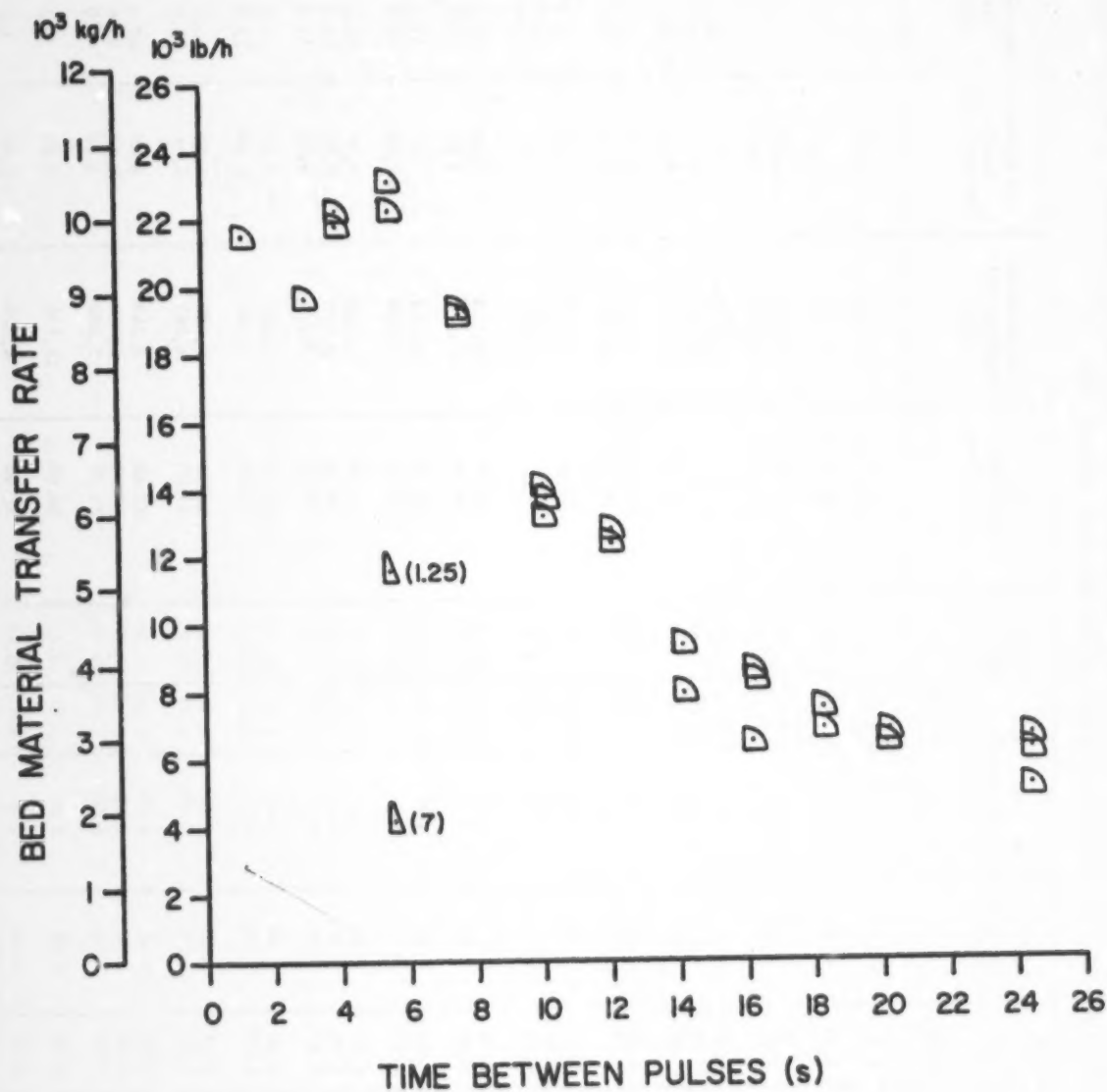


Figure 4.13 Primary Gasifier-Regenerator Bed-Material Transfer Slot--
 Fourth Generation--Frequency and Duration Tests With Sparger
 Bleed Air--Bed-Material Transfer Rate vs. Time Between Pulses

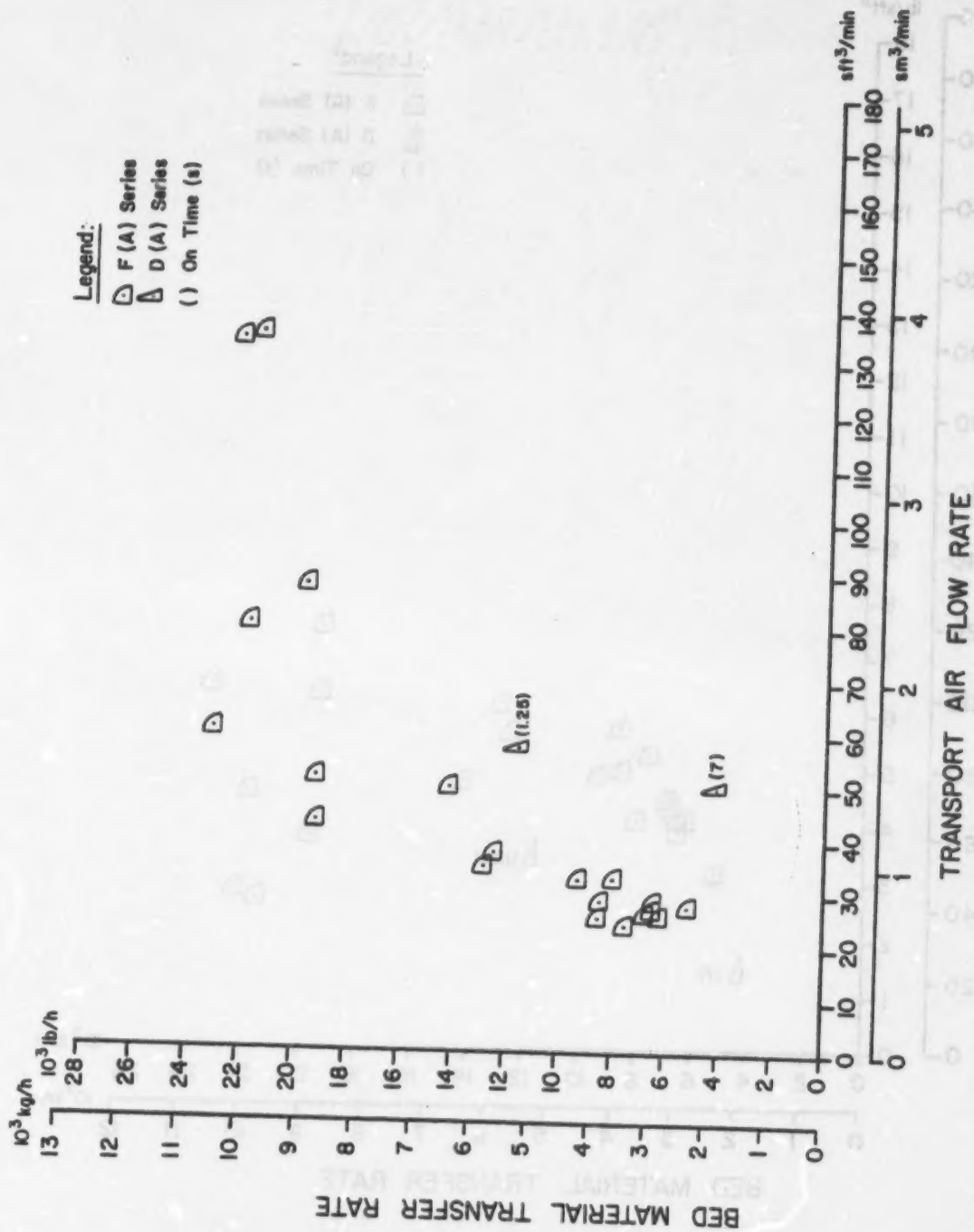


Figure 4.14 Primary Gasifier-Regenerator Bed-Material Transfer Slot---Fourth Generation---Frequency and Duration Tests With Sparger Bleed Air---Bed-Material Transfer Rate vs. Transport-Air Flow Rate

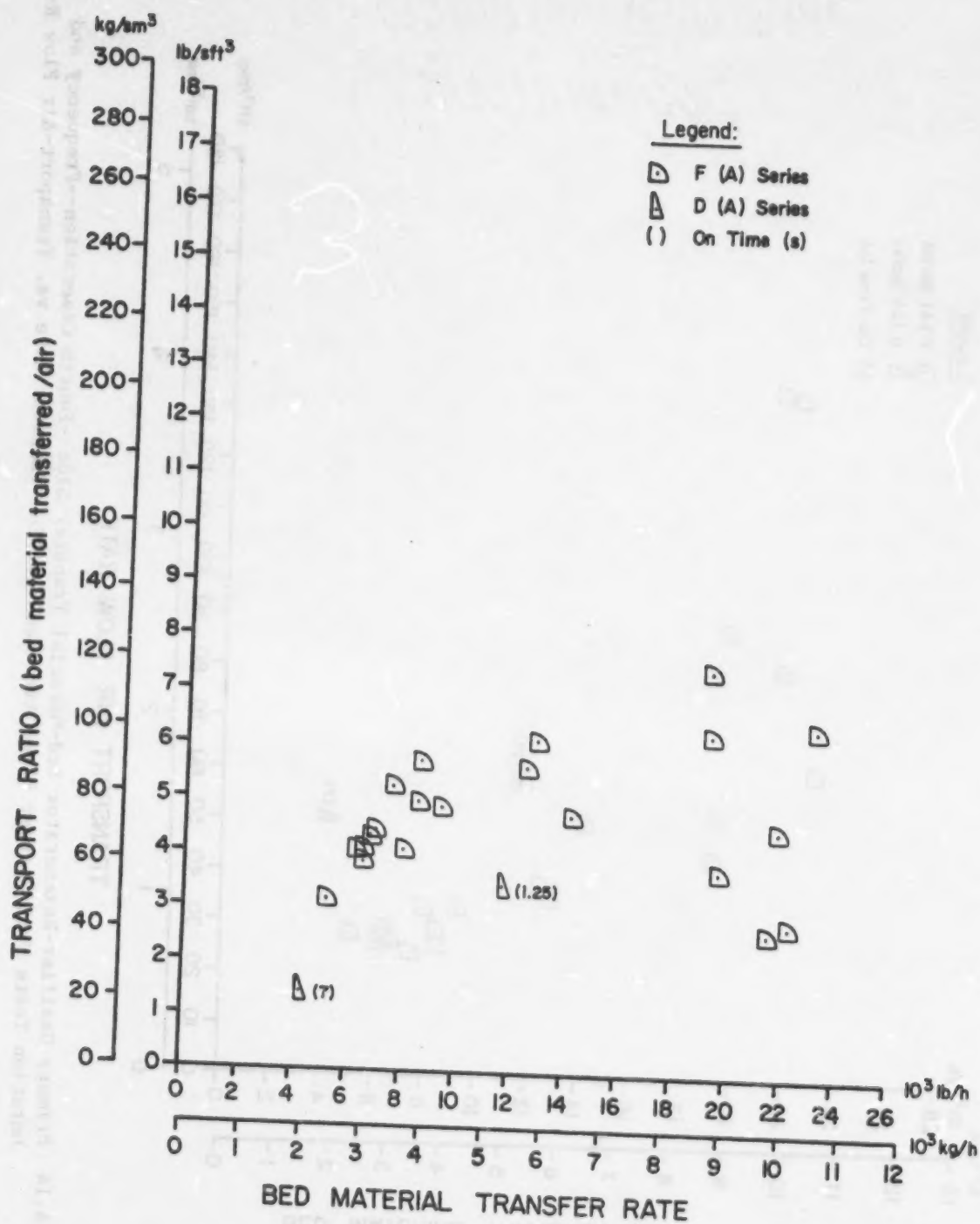


Figure 4.15 Primary Gasifier-Regenerator Bed-Material Transfer Slot--Fourth Generation--Frequency and Duration Tests With Sparger Bleed Air--Transport Ratio vs. Bed-Material Transfer Rate

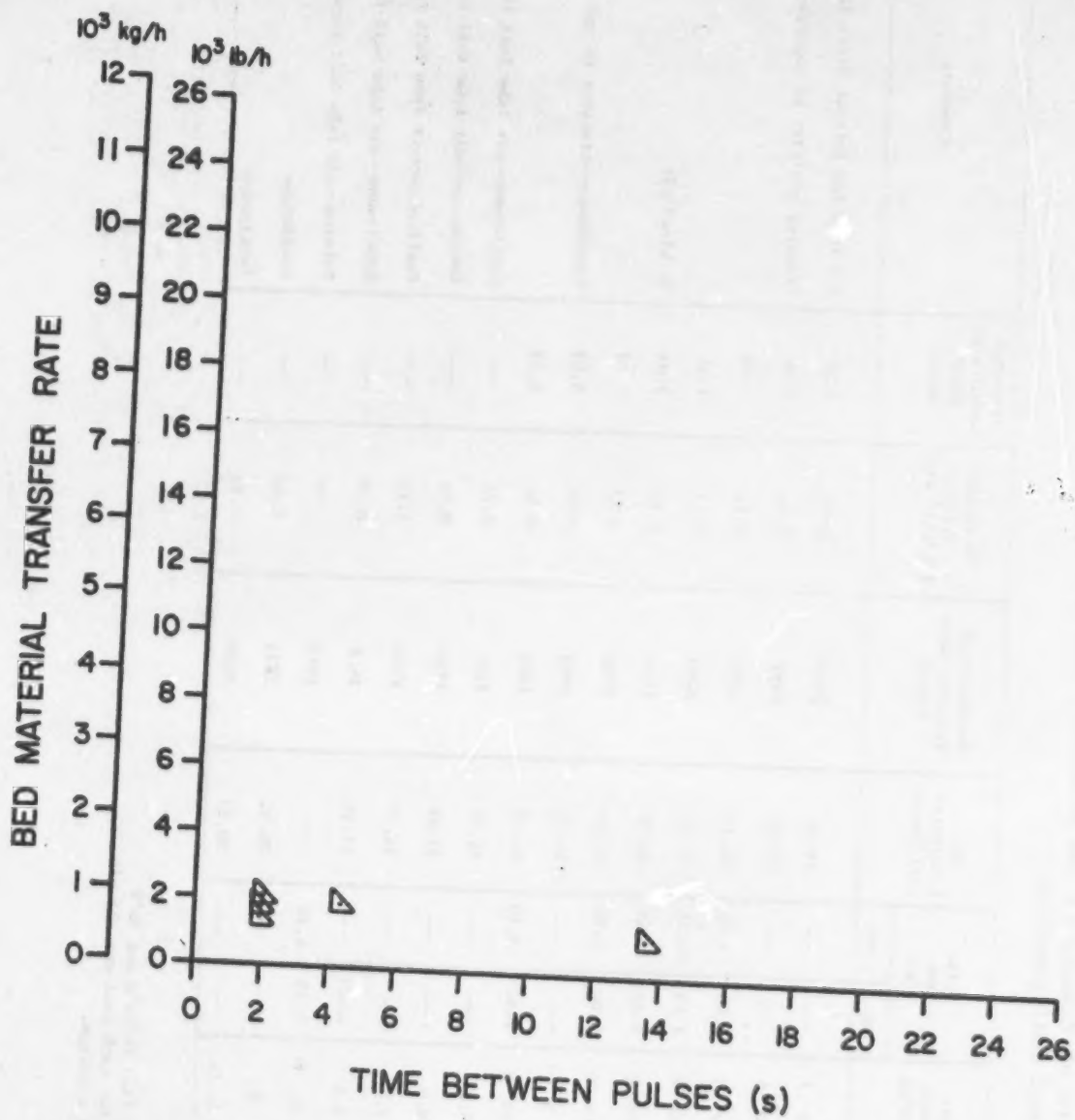
Table 4.8 Summary of Results of the Alternate Gasifier-Regenerator Bed-Material Transfer Slot--
Original Configuration

Test No.	Air Flow/Rate (lb/min)	Sparger Pressure (lb/in ² g)	Pulse Time (s)		Air Flow/Rate* (scf/min)	Bed-Material Transfer Rate (lb/h)	Transport Ratio (lb/scf [†] air)	Transport Measurement Time† (min)	Comments
			On	Off					
1	4.11	2 to 7	---	---	54.85	2210	0.67	1.35	Air tube far left of 5-in. dia. tube Transfer gasifier to regenerator only
2	3.77	2 to 6	---	---	50.35	1992	0.66	5.00	
3	4.62	2 to 8	1.65	1.85	61.71	1930	0.52	1.20	
4	2.64	2 to 8	1.65	13.45	35.26	1200	0.57	2.10	
5	2.74	0 to 4	1.65	1.85	36.57	1470	0.67	2.03	No bleed air
6	5.04	2 to 8	13.00	1.85	67.32	2100	0.52	1.10	
7	4.44	5	---	---	59.24	2988	0.84	5.00	Continuous--transfer in one direction
8	4.21	2 to 8	1.65	4.40	56.24	1960	0.59	1.32	
9	3.875	4.8	---	---	51.73	2250	0.72	---	Continuous--air tube full forward
10	5.815	10.0	---	---	77.61	2130	0.46	---	
11	2.155	2.0	---	---	28.70	1980	1.15	---	Continuous--air tube full forward
12	3.865	4.8	---	---	51.48	2418	0.78	---	
13	---	2 to 8	1.65	4.40	---	1980	---	---	Continuous--air tube half forward
14	1.975	5	---	---	26.31	2333	1.48	---	
15	3.775	13 to 14	---	---	50.37	2490	0.82	---	Continuous

*Standard conditions are 14.7 lb/in² a and 70°F.

†Typical operating time for each test was ≈15 min.

‡Calculated from annubar readings.



Legend:

△ PULSING MODE

Figure 4.16 Alternate Gasifier-Regenerator Bed-Material Transfer Slot--Original Configuration--Bed-Material Transfer Rate vs. Time Between Pulses

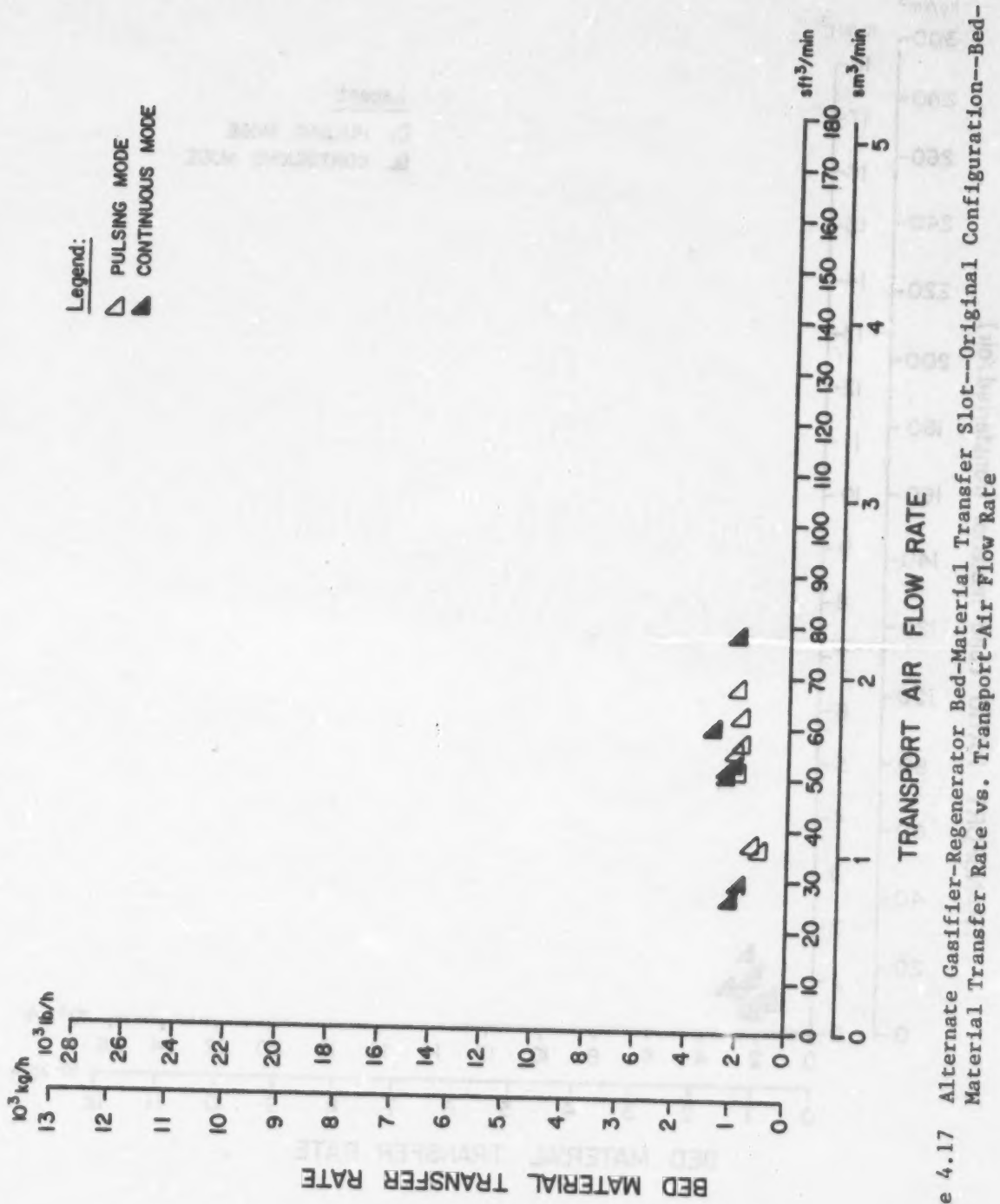


Figure 4.17 Alternate Gasifier-Regenerator Bed-Material Transfer Slot--Original Configuration--Bed-Material Transfer Rate vs. Transport-Air Flow Rate

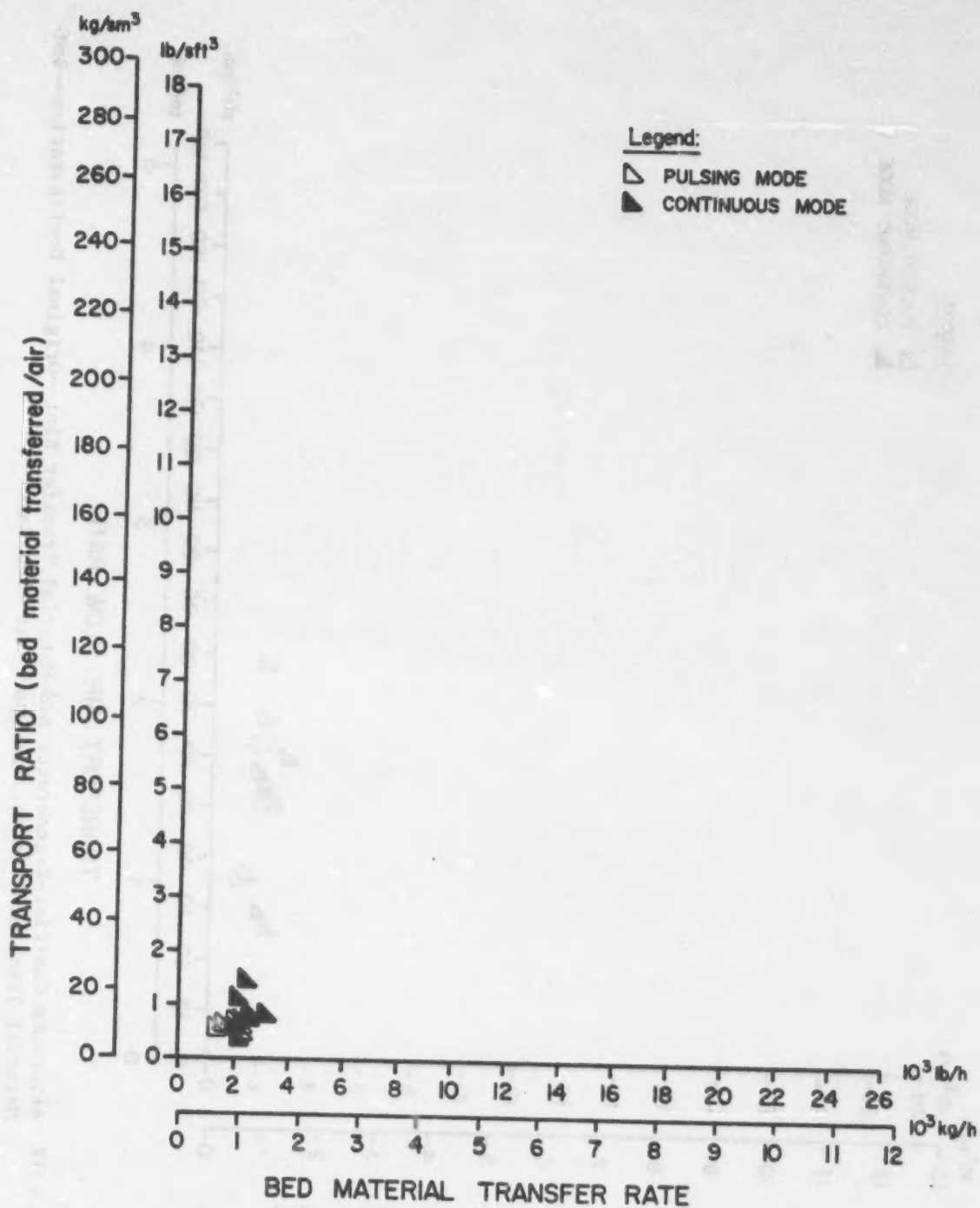


Figure 4.18 Alternate Gasifier-Regenerator Bed-Material Transfer Slot--Original Configuration--Transport Ratio vs. Bed-Material Transfer Rate

Table 4.9 Summary of Results of the Final Gasifier-Regenerator Bed-Material Transfer Slot--
Perforated-Plate Sparger

Test No.	Plenum Superficial Velocity (ft/s)		Above-Bed Superficial Velocity (ft/s)		Air Flow Rate (lb/min)	Sparger Pressure (lb/in ² g)	Pulse Time (s)		Air Flow/Rate* (scf ³ /min)	Bed-Material Transfer Rate (lb/h)	Transport Ratio (lb/scf ³ air)	Transport Air Measurement Time† (min)
	Gas	Regen.	Gas	Regen.			On	Off				
L0	6.17	5.64	6.97	6.37	2.74	0 to 3	0.5	1.85	36.54	20,080	9.16	2.00
LOR ₁	4.51	5.62	5.03	6.27	3.40	0 to 3	0.5	1.85	45.36	19,880	7.31	1.61
LOR ₂	6.42	6.69	7.34	7.65	2.39	0 to 3.5-4.1	0.5	1.85	31.97	18,400	9.59	2.28
L1	5.96	6.27	6.81	7.16	1.98	0 to 3-3.5	0.5	3.5	26.41	16,160	10.20	2.76
L1R ₁ §	5.80	6.76	6.54	7.63	1.07	0 to 3.5-4.0	0.2	3.4	14.35	7,590	8.81	5.08
L1R ₂ §	6.35	6.68	7.17	7.54	0.96	0 to 3.0-3.5	0.4	3.5	12.80	6,120	7.97	5.70
L2	6.37	6.63	7.28	7.58	1.42	0 to 3.0	0.5	6.30	18.93	7,650	6.73	3.85
L3	6.01	6.55	6.87	7.49	0.94	0 to 3-4	0.5	8.80	12.53	2,960	3.94	5.82

*Standard conditions are 14.7 lb/in²a and 70°F.

†Typical operating time for each test was ≈15 min.
§Questionable.

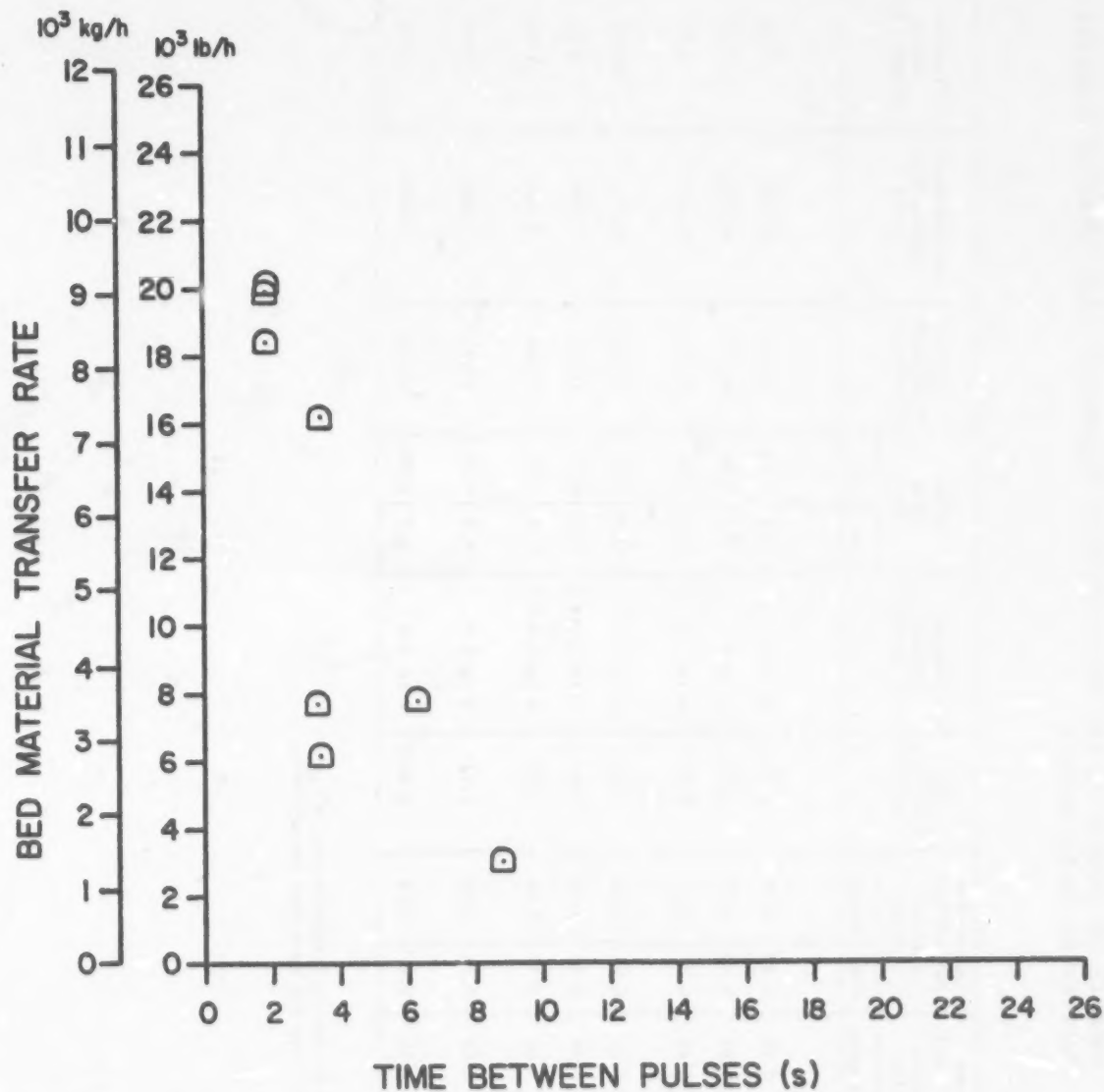


Figure 4.19 Final Gasifier-Regenerator Bed-Material Transfer Slot—
Perforated-Plate Sparger--Bed-Material Transfer Rate vs.
Time Between Pulses

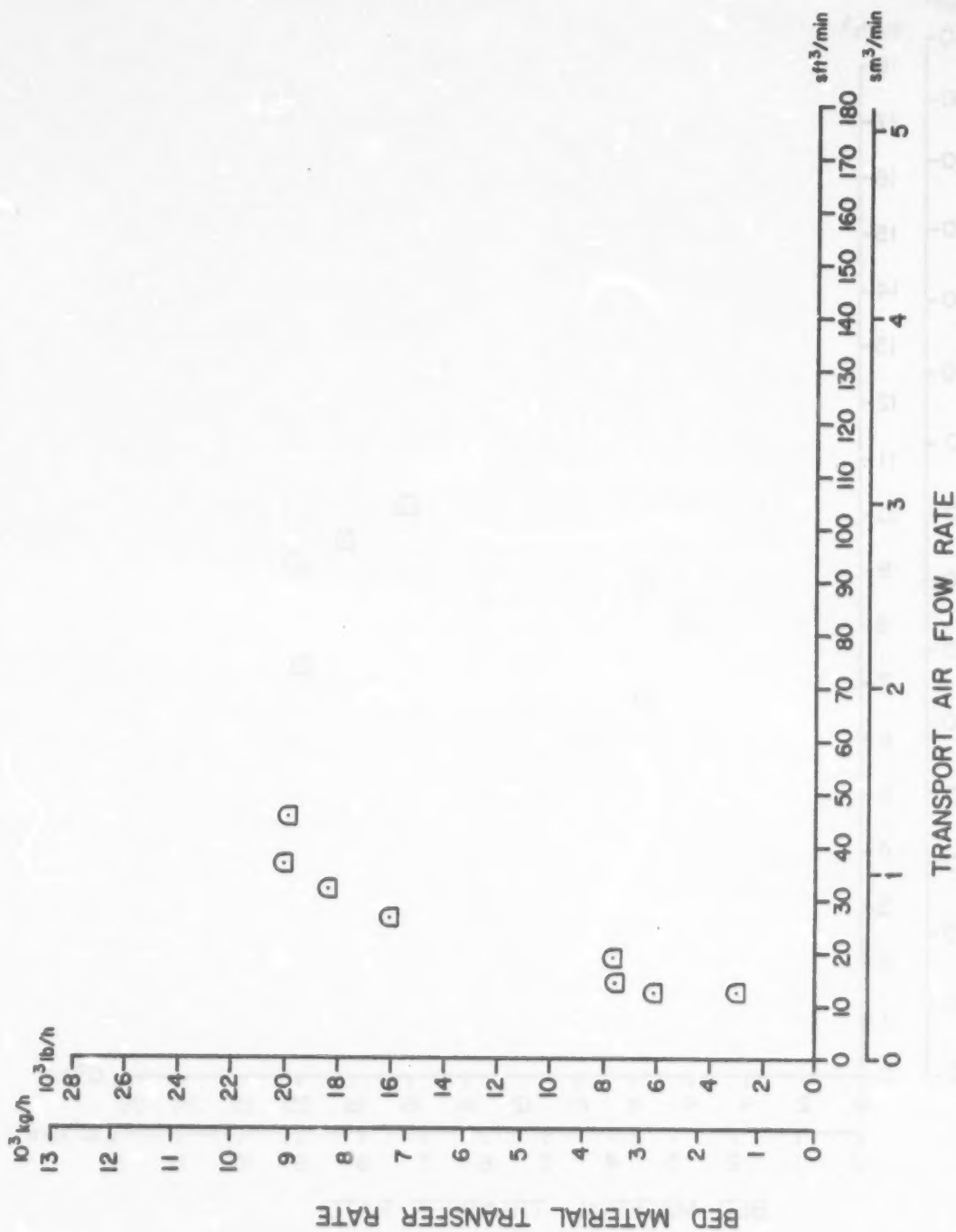


Figure 4.20 Final Gasifier-Regenerator Bed-Material Transfer Slot---Perforated-Plate Sparger--Bed Material Transfer Rate vs. Transport-Air Flow Rate

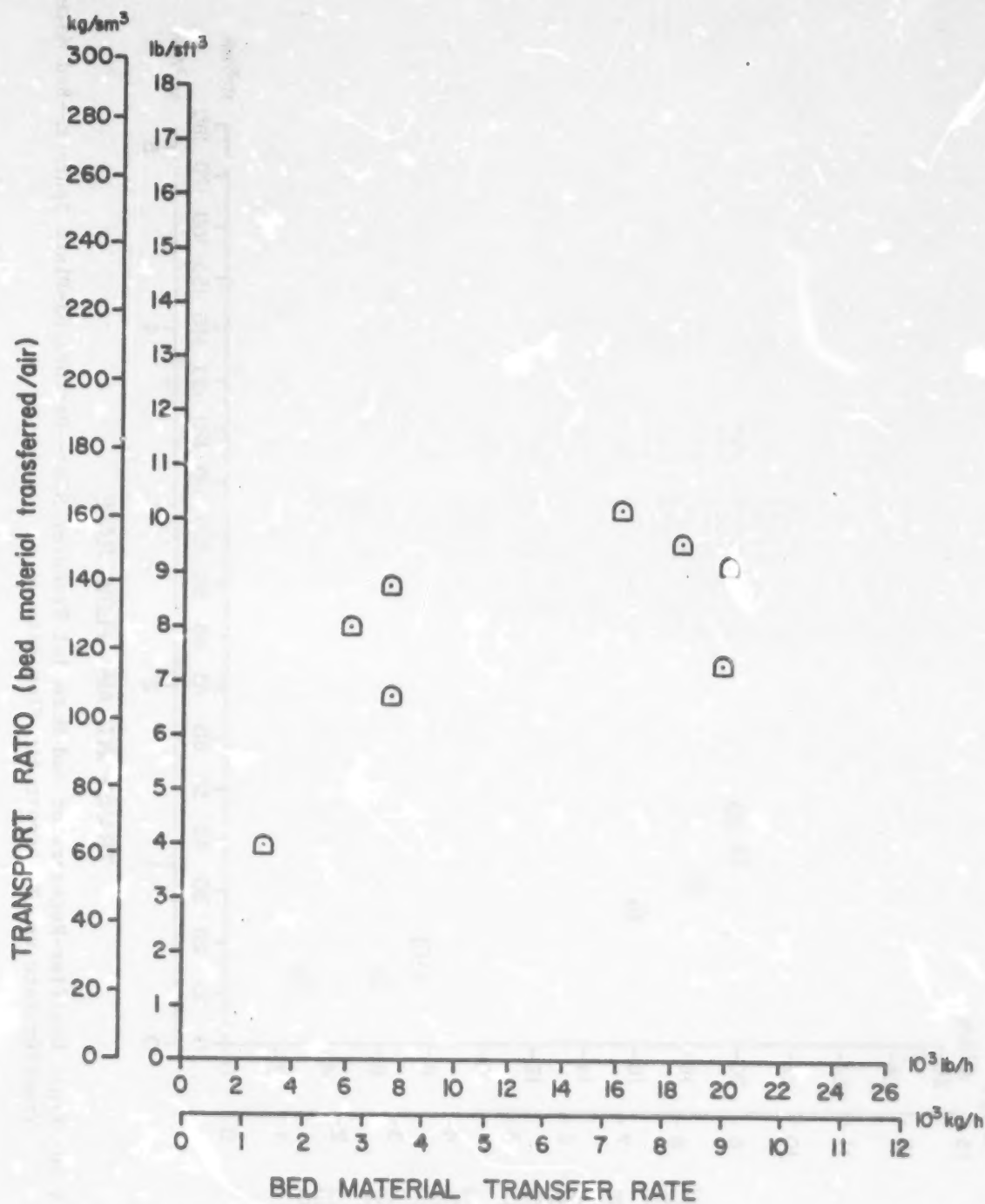


Figure 4.21 Final Gasifier-Regenerator Bed-Material Transfer Slot--Perforated-Plate Sparger--Transport Ratio vs. Bed-Material Transfer Rate

4.6.2 Three-Tube Sparger Tests

To alleviate the sparger pluggage problem mentioned in Section 4.6.1 (and more fully described in Section 3.4.1), a new sparger was designed. This final sparger design is shown alone in Figure 3.10 and in conjunction with the final gasifier-regenerator bed-material transfer slot in Figure 3.11. This system was tested and fulfilled all the performance criteria specified in Section 4.1. A summary of the tests performed is presented in Table 4.10, and calculation sheets are presented in Appendix I. These data are graphically presented as bed-material transfer rate versus time between pulses, transport-air flow rate, and transport ratio in Figures 4.22 through 4.24.

4.7 COMBINED RESULTS

Although the data presented in Figures 4.8 through 4.24 accurately demonstrate the response of the dependent variable to the independent variable, the scattering of the data points (as well as the inclusion of some questionable points) makes a direct comparison of the several candidate bed-material transfer systems difficult. By eliminating some questionable points and coalescing repeated points by means of averaging, data trends became more obvious and could be depicted for all data sets on a single graph. Such graphical representations of the data (including trend lines) are presented in Figures 4.25 through 4.27. Once again these data are presented as bed-material transfer rate versus time between pulses, transport-air flow rate, and transport ratio.

4.8 VISUAL RESULTS

In addition to the quantitative results described above, qualitative results were obtained in the form of a 16-mm movie. A copy of this film is appended to the EPA Project Officer's copy of this report. The film offers a visual comparison of the three slot geometries tested: the primary gasifier-regenerator bed-material transfer slot--fourth generation, the alternate gasifier-regenerator bed-material transfer slot, and the final gasifier-regenerator bed-material transfer slot using the three-tube sparger. Table 4.11 presents test numbers and other pertinent information for the film.

Table 4.10 Summary of Results of the Final Gasifier-Regenerator Bed-Material Transfer Slot---
Three-Tube Sparger

Test No.	Plenum Superficial Velocity (ft/s)		Above-Bed Superficial Velocity (ft/s)		Air Flow Rate (lb/min)	Sparger Pressure (lb/in ² g)	Pulse Time (s)		Air Flow Rate* (scf ³ /min)	Bed-Material Transfer Rate (lb/h)	Transport Ratio (lb/scf ³ air)	Transport Air Measurement Time† (min)
	Gas.	Regen.	Gas.	Regen.			On	Off				
LS-1	5.60	6.33	6.28	7.10	1.58	0 to 2.5	0.5	7.5	21.13	10,605	8.36	3.47
LS-2	5.64	6.37	6.33	7.15	1.46	0 to 2.5	0.7	9.2	19.54	9,600	8.19	3.76
LS-3	5.64	6.37	6.33	7.15	1.14	0 to 2.5	0.5	12.0	15.27	6,840	7.47	4.81
LS-4	5.83	6.40	6.55	7.10	3.96	0 to 2.5	0.5	2.6	52.89	18,880	5.95	1.40
LS-4R	6.60	6.07	7.50	6.90	3.66	0 to 2.5	0.5	2.6	40.82	19,560	6.68	1.52
LS-5	6.63	6.27	7.53	7.12	2.92	0 to 2.5	0.5	4.0	38.97	16,060	6.87	1.90
LS-5R	6.60	6.07	7.50	6.90	2.73	0 to 2.5	0.5	4.0	36.42	15,760	7.21	2.03
LS-6S	6.67	6.34	7.53	7.16	1.97	0 to 2.5	0.5	7.0	26.29	13,040	8.27	2.82
LS-7H												
LS-8 (Continuous)	6.72	6.37	7.59	7.19	7.74	1.5 to 2.5	---	---	103.33	12,360	1.99	0.72

*Standard conditions are 14.7 lb/in² a and 70°F.

†Typical operating time for each test was =15 min.

‡Good operating point.

§No values. Attempts to imbalance beds failed.

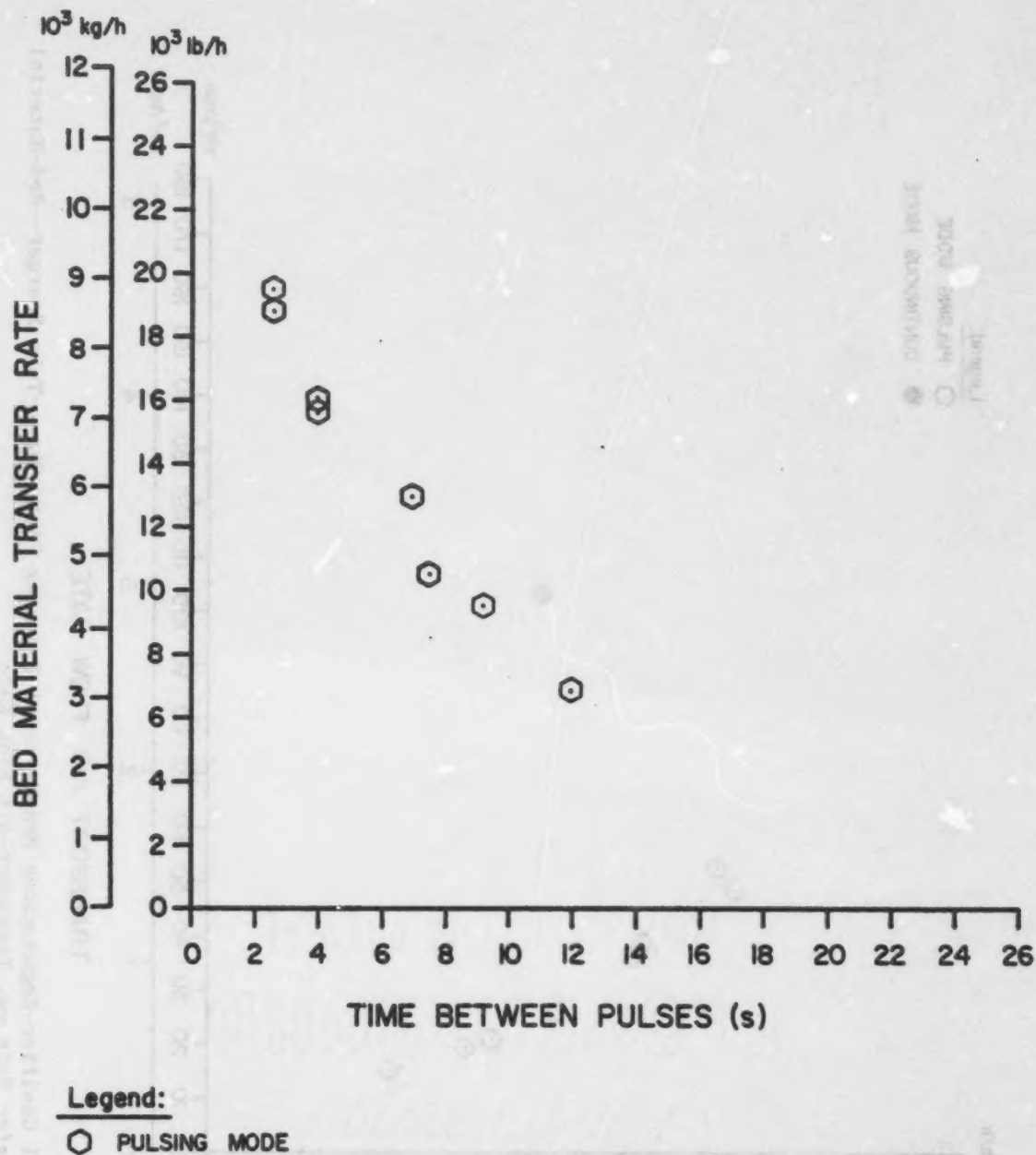


Figure 4.22 Final Gasifier-Regenerator Bed-Material Transfer Slot--
Three-Tube Sparger--Bed-Material Transfer Rate vs. Time
Between Pulses

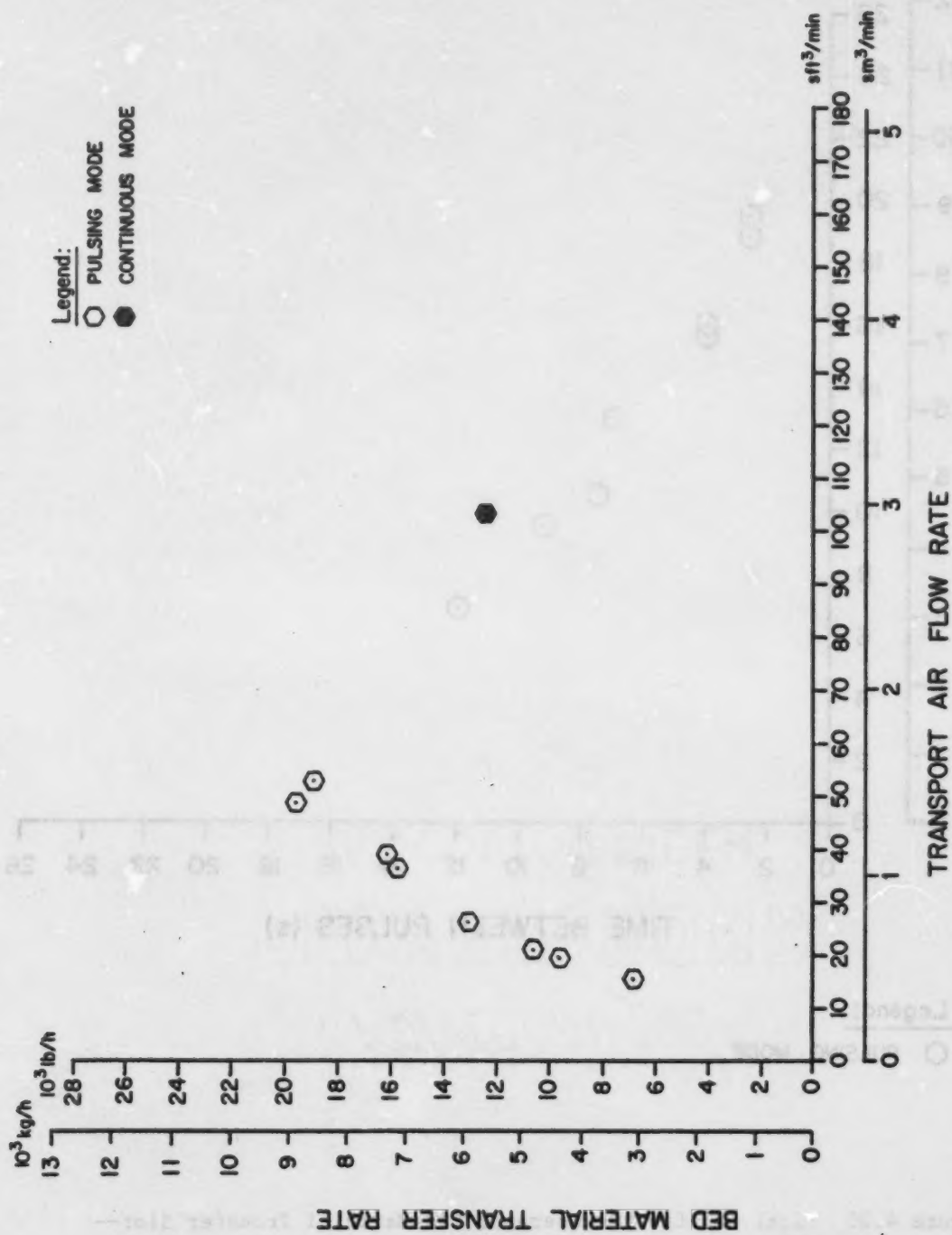


Figure 4.23 Final Gasifier-Regenerator Bed-Material Transfer Slot---Three-Tube Sparger---Bed-Material Transfer Rate vs. Transport-Air Flow Rate

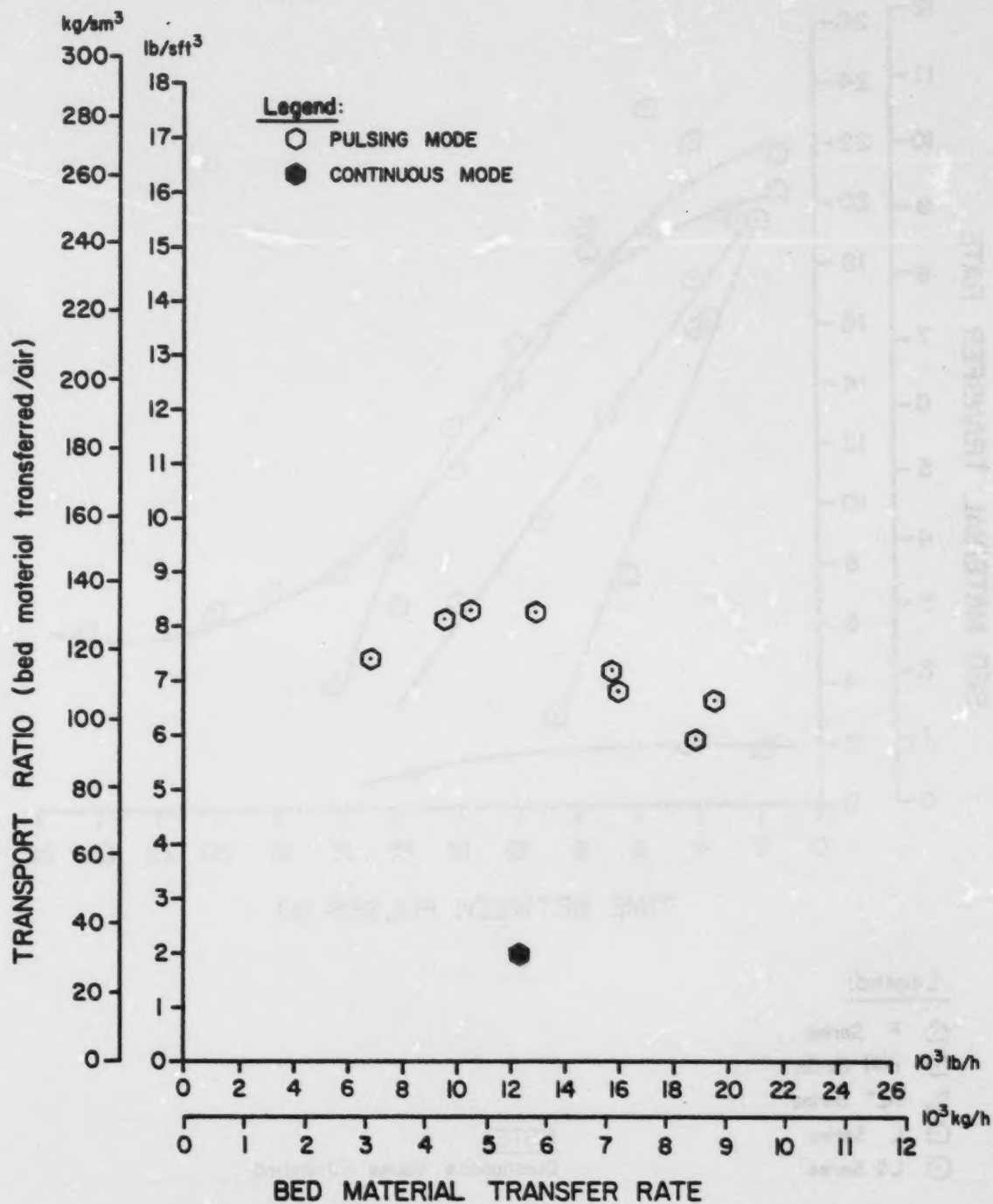
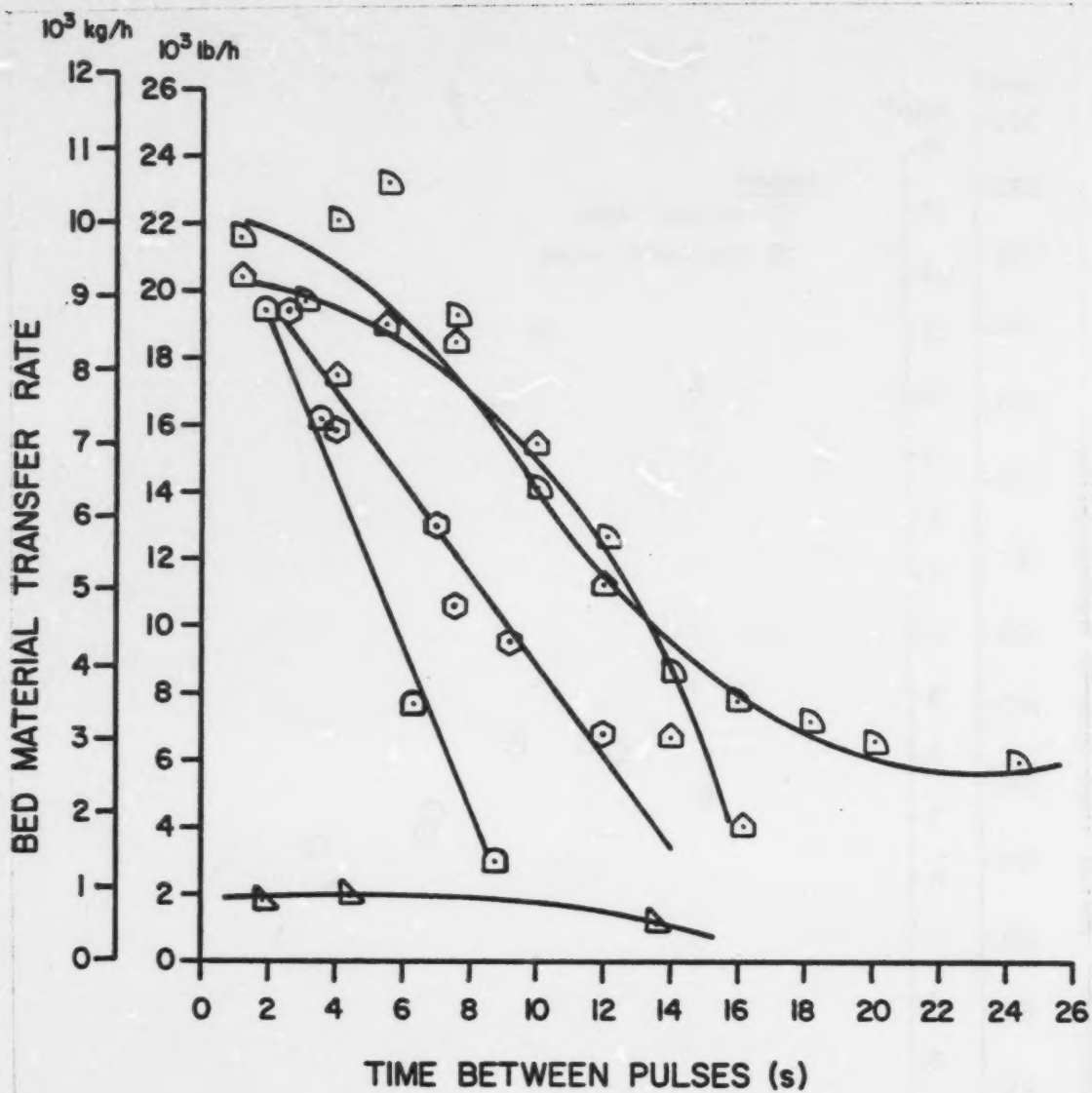


Figure 4.24 Final Gasifier-Regenerator Bed-Material Transfer Slot--Three-Tube Sparger--Transport Ratio vs. Bed-Material Transfer Rate



Legend:

- △ F Series
- ◊ F(A) Series
- ▽ ALT Series
- L Series
- LS Series

NOTE:

Questionable Values Eliminated

Figure 4.25 Combined Results of Gasifier-Regenerator Bed-Material Transfer System--Bed-Material Transfer Rate vs. Time Between Pulses

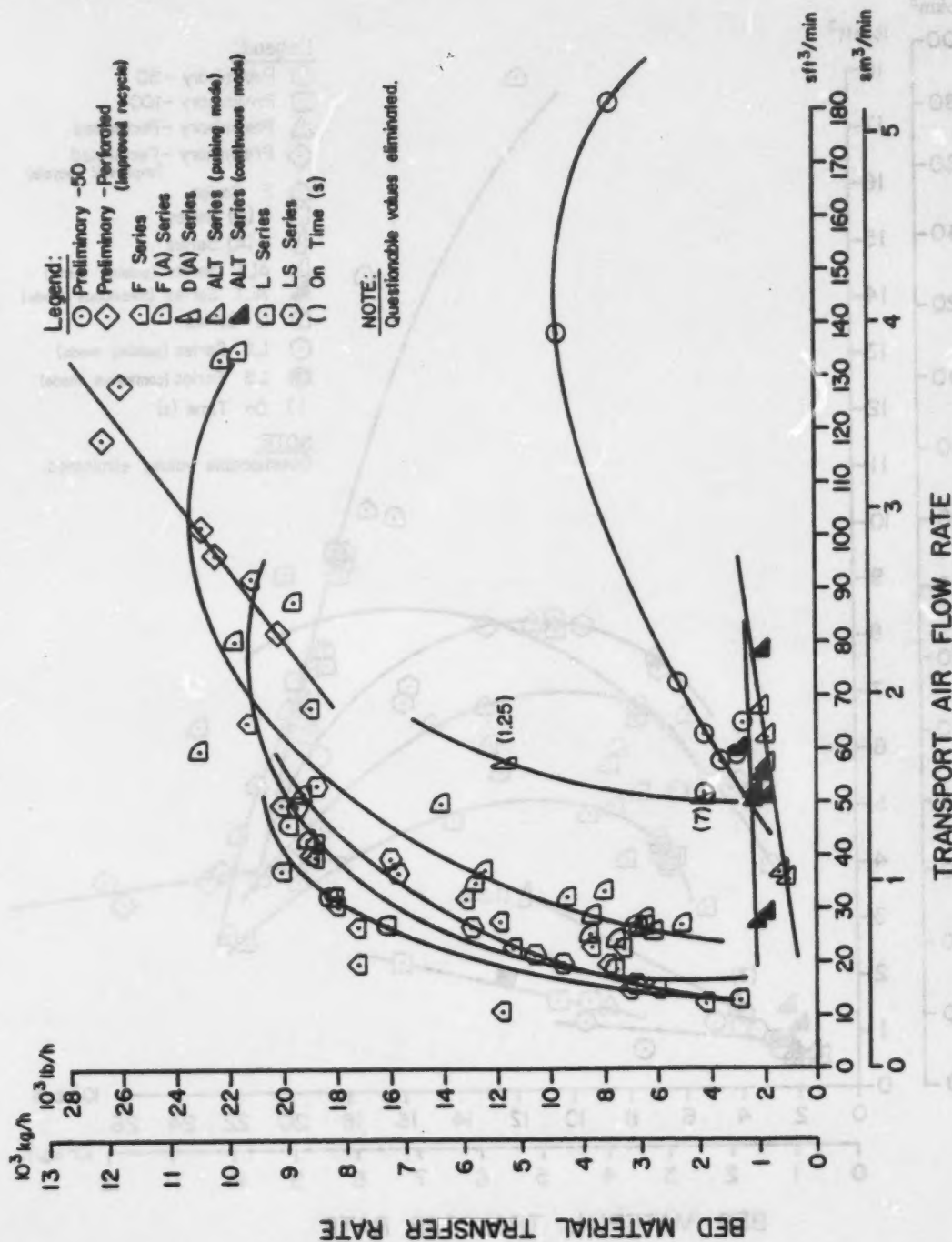


Figure 4.26 Combined Results of Gasifier-Regenerator Bed-Material Transfer System--Bed-Material Transfer Rate vs. Transport-Air Flow Rate

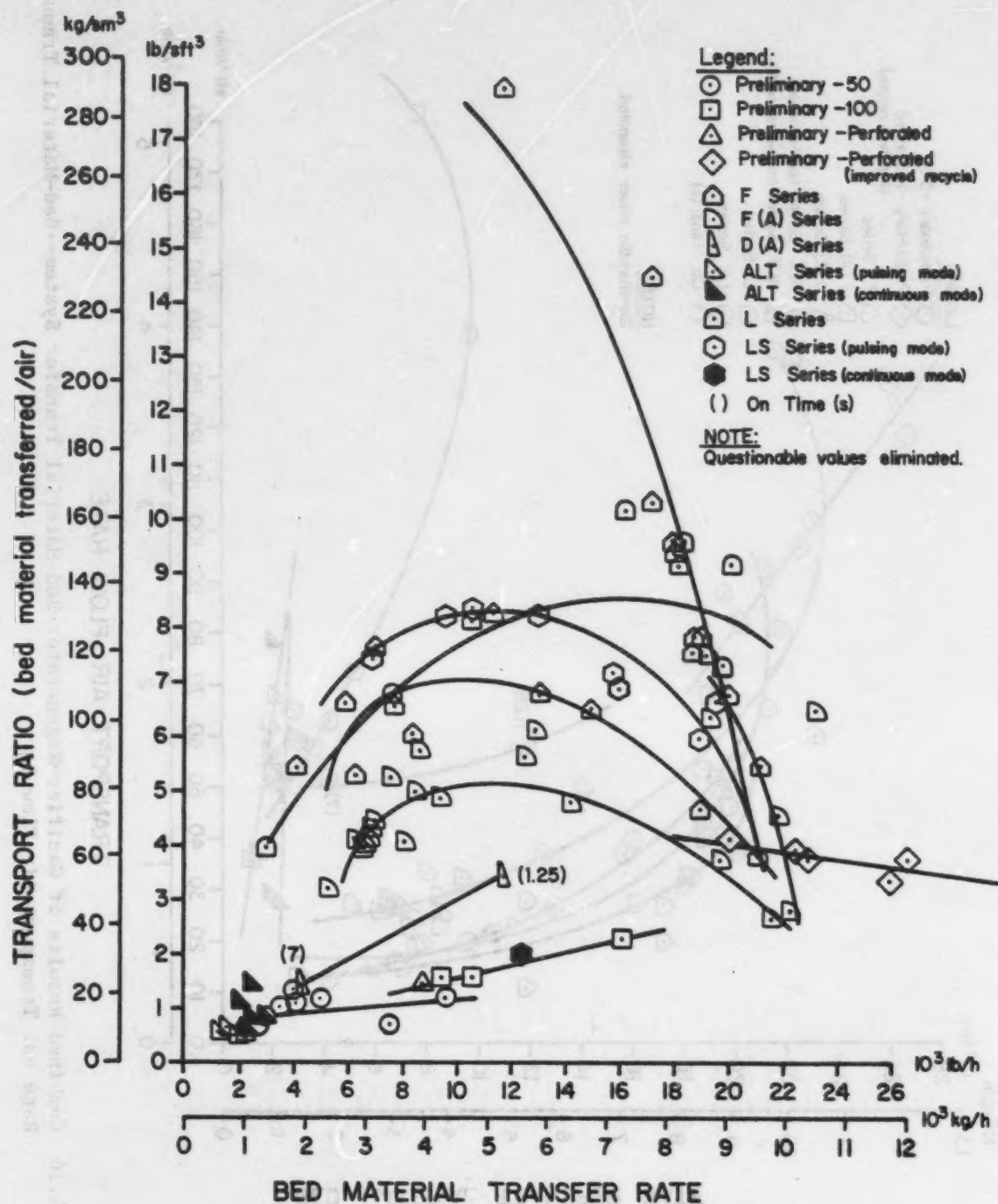


Figure 4.27 Combined Results of Gasifier-Regenerator Bed-Material Transfer System—Transport Ratio vs. Bed-Material Transfer Rate

Table 4.11 Visual Results of Gasifier-Regenerator Bed-Material Transfer Systems Tested in CAFB Cold Model

Film Section	Gasifier-Regenerator Bed-Material Transfer Slot	Test No.	Sparger Bleed Air (On/Off)	Sparger Pressure (lb/in ² g)	Timer Pulses (s) (On/Off)	Bed-Material Transfer Rate (lb/h)	Transport Ratio (lb/sft ³ air) ^a
1	Primary-Fourth Generation	D-0(A)	On	7	1.25/5.45	11,730	3.60
2	Alternate	Alt-1	---	5	Continuous	2,100	1.33
3	Final Three-Tube	L-S-6	Off	2.5	0.5/7.0	13,040	8.30

^aStandard conditions are 14.7 lb/in²a and 70°F.

Section 5

DISCUSSION OF RESULTS

5.1 QUANTITATIVE RESULTS

5.1.1 Basis of Comparison

The quantitative test results are contained in the information presented in Appendices D through I, which represent a reduction of the "raw" data using the procedure outlined in Appendix C. As stated under performance criteria (Section 4.1), the optimum bed-material transfer system should have the following specifications:

- Transfer large amounts of bed material per unit time between two operating fluidized beds
- Use the minimum quantity of activating gas
- Maintain the minimum activating gas pressure
- Allow only minimal gas leakage back into the "supply" bed
- Provide an accurate and reliable control of the transfer rate.

As a result of this optimum bed-material transfer system specification, the variables of prime importance are:

- Bed-material transfer rate
- Transport-air flow rate
- Sparger pressure
- Time between pulses.

Data summaries, containing values of these primary variables, for each gasifier-regenerator bed-material transfer slot configuration tested are presented in Tables 4.5 through 4.10. With respect to the optimum bed-material transfer system specification, the system exhibiting the highest bed-material transfer rate using the smallest amount of transport air and the lowest sparger pressure (while maintaining a high level of controllability and reliability) would be judged the best.

In an effort to illustrate data trends and provide a visual comparison of the several systems tested, the graphs presented in Figures 4.8 through 4.27 were constructed. The variable relationships presented in these graphs are:

- Bed-material transfer rate versus time between pulses
- Bed-material transfer rate versus transport-air flow rate
- Transport ratio versus bed-material transfer rate.

Transport ratio was defined in Section 4.3 as the amount of bed material transferred by 1 sft³ of activating gas (standard conditions are 14.7 lb/in²a and 70°F). This ratio can be used as a measure of the efficiency of a bed-material transfer system, with the more efficient systems having higher values of the transport ratio.

With respect to the controllability and reliability of the systems tested, both the scatter and linearity of the frequency (time between pulses) and transport-air flow rate versus bed-material transfer rate are important. The higher the degree of linearity and the lower the degree of scatter, the greater the controllability and reliability (reproducibility) of the system. Both scatter and linearity of the data are illustrated in the graphs presented in Figures 4.8 through 4.27.

In an attempt to quantify both measures of controllability and reliability, the data correlations presented in Tables 5.1 through 5.4 were constructed. Tables 5.1 through 5.3 quantify the data scatter, which is illustrated in the graphs, by calculating:

- Average values for both the independent and dependent variables
- Standard deviation for both independent and dependent variables
- Data correlation coefficient
- Coefficients of variation for both the independent and dependent variables.

The linearity of both measures of controllability and reliability is quantified in Table 5.4 through the calculation of the slope, intercept, and linear correlation coefficient (for bed-material transfer rate versus both time between pulses and transport-air flow rate) by the least-squares method.

5.1.2 Primary Gasifier-Regenerator Bed-Material Transfer System— Preliminary Tests

5.1.2.1 Overall Preliminary Testing Results. The preliminary tests performed using the Primary-Gasifier Regenerator Bed-Material Transfer System (third- and fourth-generation transfer slots) demonstrated a consistent improvement in operation (as determined by means of comparison with the ideal system specification given in Section 5.1.1) as the third- and fourth-generation changes (as described in Sections 3.2.4 and 3.2.5) were incorporated. In general, as successive geometry and/or sparger changes were incorporated, the trend

Table 5.1 Data Scatter Correlation--Bed-Material Transfer Rate vs. Time Between Pulses

Test Series	No. of Points Used in Correlation n	Average Values		Standard Deviation		Correlation Coefficient (α_{xy})	Coefficients of Variation	
		Time (s)	Material Rate (lb/h)	Time (s)	Material Rate (lb/h)		$V_x (z)$	$V_y (z)$
Preliminary: 50-hole sparger								
100-hole sparger								
100-hole sparger								
Perforated-plate sparger								
Perforated-plate sparger								
Frequency	23	8.76	14,258	4.64	5,476	-0.85	52.97	38.39
Frequency (A)	26	8.96	14,209	4.41	5,201	-0.84	49.11	36.60
Alternate	22	13.31	12,428	7.25	6,459	-0.94	54.47	51.97
Final:	5	4.68	1,736	5.03	383	-0.73	107.48	22.06
Perforated-plate sparger	6	4.93	14,188	2.91	7,177	-0.99	72.21	50.59
Perforated-plate sparger	8	3.88	12,355	2.48	6,962	-0.81	63.92	56.35
3-tube sparger	8	6.11	13,793	3.39	4,548	-0.98	55.48	32.97
3-tube sparger	9	---	---	---	---	---	---	---

*Coefficient of variation = (100) (standard deviation)/(average value).

†Questionable points deleted.

‡Continuous run deleted.

Note:

1. The average values (measure of central tendency) are defined by:

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i \quad \bar{y} = \frac{1}{n} \sum_{i=1}^n y_i$$

2. The standard deviations (measures of absolute variation) are defined by:

$$s_x = \left[\frac{\sum_{i=1}^n x_i^2 - n \bar{x}^2}{(n-1)} \right]^{1/2}$$

$$s_y = \left[\frac{\sum_{i=1}^n y_i^2 - n \bar{y}^2}{(n-1)} \right]^{1/2}$$

3. The correlation coefficient (a measure of the linear correlation between two variables) is defined by:

$$\alpha_{xy} = \frac{1}{n-1} \left(\sum_{i=1}^n x_i y_i - \frac{1}{n} \sum_{i=1}^n x_i \sum_{i=1}^n y_i \right) / (s_x s_y)$$

When α_{xy} is positive y increases as x increases; when α_{xy} is negative y decreases as x increases.

4. The coefficients of variation (measures of relative variation) are defined by:

$$V_x = \frac{s_x}{\bar{x}} (100) \quad \text{and} \quad V_y = \frac{s_y}{\bar{y}} (100)$$

5. Summations are from $i = 1$ to $i = n$.

Table 5.2 Data Scatter Correlation--Bed-Material Transfer Rate vs. Transport-Air Flow Rate

Test Series	No. of Points Used in Correlation (n)	Average Values		Standard Deviation		Correlation Coefficient (α_{xy})	Coefficients of Variation ^a	
		Air Rate [†] (scf ³ /min)	Material Rate (lb/h)	Air Rate (scf ³ /min)	Material Rate (lb/h)		V_x (%)	V_y (%)
Preliminary:								
50-hole sparger	8	86.18	4,951	47.28	2416	0.855	54.86	48.84
100-hole sparger [§]	3	110.47	12,016	9.23	3533	0.850*	8.36	29.40
100-hole sparger	5	112.49	9,566	7.39	4212	0.11	6.57	44.03
Perforated-plate sparger [§]	5	105.35	23,650	18.53	2689	0.965	17.58	11.37
Perforated-plate sparger	12	117.05	19,366	26.38	5175	-0.02	22.54	26.72
Frequency [§]	23	33.56	14,258	19.80	5474	0.74	59.00	38.39
Frequency	26	31.79	14,209	19.46	5201	0.71	61.21	36.60
Frequency (A)	22	47.20	12,428	33.12	6459	0.81	70.17	51.97
Alternate	14	50.55	2,105	14.57	430	0.32	28.82	20.43
Final:								
Perforated-plate sparger [§]	6	28.62	14,188	11.93	7177	0.92	41.68	50.59
Perforated-plate sparger	8	24.86	12,355	12.26	6962	0.94	49.32	56.35
3-tube sparger ^{††}	8	32.42	13,793	14.00	4548	0.98	43.18	32.97
3-tube sparger	9	40.30	13,634	27.02	4281	0.37	67.05	31.40

^aCoefficient of variation $\equiv$ (100) (standard deviation)/(average value).

[†]Standard conditions are 14.7 lb/in²a and 70°F.

[§]This value is of questionable significance (see text).

[¶]Questionable points deleted.

^{*}Insufficient number of data points.

^{††}Continuous run deleted.

Note: For definitions of above variables (e.g., α_{xy}) see Note on Table 5.1.

Table 5.3 Data Scatter Correlation--Transport Ratio vs. Bed-Material Transfer Rate

Test Series	No. of Points Used in Correlation (n)	Average Values		Standard Deviation		Correlation Coefficient (α_{xy})	Coefficients of Variation	
		Material Rate (g) (lb/h)	Transport Ratio (y)* (lb/ft ² air)	Material Rate (S _x) (lb/h)	Transport Ratio (S _y) (lb/ft ² air)		V _x (%)	V _y (%)
Preliminary:								
50-hole sparger	8	4,327	1.00	2972	0.23	-0.04	68.69	23.00
100-hole sparger†	3	12,016	1.80	3533	0.40	+0.99§	29.40	22.22
100-hole sparger	5	9,566	1.42	4212	0.60	+0.99	44.03	42.25
Perforated-plate sparger†	5	23,650	3.78	2689	0.26	-0.82	11.37	7.01
Perforated-plate sparger	12	19,366	2.85	5175	0.96	+0.80	26.72	33.68
Frequency†	23	14,258	7.94	5474	3.14	+0.06	38.39	39.55
Frequency	26	14,209	9.02	5201	5.46	+0.01	36.60	60.53
Frequency (Δ)	22	12,428	4.71	6459	1.22	+0.17	51.97	25.90
Alternate	14	2,105	0.75	430	0.27	+0.32	20.43	36.00
Vial:								
Perforated-plate sparger†	6	14,188	7.82	7177	2.33	+0.81	50.59	29.80
Perforated-plate sparger	8	12,355	7.96	6972	2.00	+0.64	56.35	25.13
3-tube sparger§	8	13,793	7.38	4548	40.87	-0.75	32.97	11.79
3-tube sparger	9	13,634	6.78	4281	+1.97	-0.20	31.40	29.06

*Standard conditions are 14.7 lb/in² a and 70°F.

†Questionable points deleted.

§Insufficient number of data points.

¶Continuous run deleted.

Note: For definitions of above variables (e.g., α_{xy}) see Note on Table 5.1.

Table 5.4 Data Linearity Correlations

Test Series	No. of Data Points Used (n)	Intercept* (a)	Slope* (b)	Linear Correlation Coefficient* (r ²)	Comments
Bed-Material Transfer Rate vs. Time Between Pulses					
(Equation: Bed Material Transfer Rate = a + b (time between pulses)†					
Preliminary: 50-hole sparger 100-hole sparger Perforated-plate sparger					No data No data No data
Frequency	23	23,031	-1001.7	0.72	Questionable points deleted
Frequency (A)	22	23,546	-835.4	0.88	Questionable points deleted
Alternate	5	1,995	-55.0	0.53	Questionable points deleted
Final: Perforated-plate sparger 3-tube sparger					
	6	24,039	-2447.5	0.99	Questionable points deleted
	8	21,844	-1317.2	0.97	Continuous run deleted
Bed-Material Transfer Rate vs. Transport-Air Flow Rate					
(Equation: Bed Material Transfer Rate = a + b (transport-air flow rate)†					
Preliminary: 50-hole sparger 100-hole sparger Perforated-plate sparger					
	8	1,204	43.5	0.72§	Insufficient number of data points
	5	8,942	139.6	0.93§	Questionable points deleted
Frequency	23	7,272	205.2	0.55	Questionable points deleted
Frequency (A)	22	4,972	157.9	0.66	Questionable points deleted
Alternate	14	1,622	9.6	0.11	Questionable points deleted
Final: Perforated-plate sparger 3-tube sparger					
	6	-1,723	555.9	0.85	Questionable points deleted
	8	3,508	317.3	0.95	Continuous run deleted

*The least-squares linear regression coefficients and the linear correlation coefficient are defined as follows:

$$b = \frac{\left(\sum x_i y_i - \frac{\sum x_i \sum y_i}{n} \right)}{\left(\sum x_i^2 - \frac{(\sum x_i)^2}{n} \right)}$$

$$a = \frac{\sum y_i}{n} - b \frac{\sum x_i}{n}$$

$$r^2 = \frac{\left(\sum x_i y_i - \frac{\sum x_i \sum y_i}{n} \right)^2}{\left(\sum x_i^2 - \frac{(\sum x_i)^2}{n} \right) \left(\sum y_i^2 - \frac{(\sum y_i)^2}{n} \right)}$$

Summations are from $i = 1$ to $i = n$.

Fit improves as r^2 approaches 1.0.

†Units: Time between pulses - seconds

Transport-air flow rate - sft³/min (14.7 lb/in²a, 70°F).

§This value is of questionable significance (see text).

in the important variables was toward higher bed-material transfer rates, lower transport-air consumption rates, and higher transport ratios (efficiencies). Few conclusions can be reached concerning the controllability and reliability (reproducibility) of the bed-material transfer systems tested during the preliminary testing period, however, because data on bed-material transfer rate versus time between pulses were not taken. Data on bed-material transfer rate versus transport-air flow rate were inconclusive but indicated that the bed-material transfer rate usually tended to increase with increasing transport-air flow rate.

Results of the preliminary tests (especially those incorporating the perforated-plate sparger and improved external recycle system) were sufficiently encouraging to justify formal testing of the Primary Gasifier-Regenerator Bed-Material Transfer System--Fourth Generation. Before the results of this formal testing are discussed, however, the results of each major category of preliminary tests will be more fully discussed.

5.1.2.2 Preliminary Tests A Through H. The preliminary tests A through H (presented in Table 4.5) refer to those tests performed on the primary gasifier-regenerator bed-material transfer slot--third generation which incorporated the rectangular sparger with fifty 9/32-in.-diameter holes. The maximum bed-material transfer rate realized during this test series was 9594 lb/h and required a transport-air flow rate of 138.23 sft³/min and a sparger pressure of 6 lb/in²g. This combination of bed-material transfer rate and transport-air flow rate produces a transport ratio of 1.16. All these results indicate a low-efficiency system requiring improvement to be usable. For example, the maximum bed-material transfer rate achieved (9,594 lb/h) was less than one-third of the nominal design requirement of 30,000 lb/h. If the system were triplicated to achieve the desired bed-material transfer rate, it would be too large for the La Palma unit and would use too much transport air (approximately 415 sft³/min per transfer unit). In addition, the 6-lb/in²g sparger pressure was considered only marginally acceptable.

As stated in Section 5.1.1, the transport ratio can be considered a quantitative measure of the efficiency of the bed-material transfer system. A review of the values presented in Table 4.5 for the 50-hole rectangular sparger shows a maximum value of 1.32, compared with a maximum value of 2.5 reported by ERCA³ during their cold modeling of the Gasifier-Regenerator Bed-Material Transfer System incorporated in their pilot plant. Obviously the new bed-material transfer system should be at least as efficient (and hopefully considerably more efficient) than a previously existing system.

With respect to controllability and reliability (reproducibility), data is only available on how a change in the transport-air flow rate affects the bed-material transfer rate. The data trend is shown in Figure 4.26. The fact that the bed-material transfer rate reached a maximum value and then declined with increasing transport-air flow rate suggests that this system would be limited to a maximum bed-material transfer rate of approximately 10,000 lb/h. Although the quantitative measures of data scatter and linearity (Tables 5.2 and 5.4) suggest a high level of correlation and a moderate degree of linearity

for the bed-material transfer rate versus transport-air flow rate, the clustering of a large percentage of the data points (as evidenced in Figure 4.26) could have unduly affected the accuracy of these measures, and therefore no definitive conclusions can be drawn.

5.1.2.3 Preliminary Tests I Through M. The preliminary tests I through M (also presented in Table 4.5) refer to those tests performed on the primary gasifier-regenerator bed-material transfer slot—fourth generation which incorporated the rectangular sparger with one hundred 9/32-in.-diameter holes. Only a small number of data points were recorded for this system, since this sparger was highly susceptible to pluggage because of back-sifting of bed material (see Section 3.2.5). As a result, no meaningful conclusions can be drawn from the small number of usable data points obtained.

5.1.2.4 Preliminary Tests N Through Y. The front face of the rectangular sparger described in Section 5.1.2.3 was replaced with a piece of perforated plate and the same system was retested. After the first two tests (N and O), the bed-height effect (described in Section 3.2.5) was observed and the improved external recycle system (also described in Section 3.2.5) was installed. Since the testing results after the improved external recycle system was installed are the most significant, only they will be addressed in the following paragraphs. Unfortunately, once again a significant portion of the data values were questionable and should not be included in an analysis. As a result, only five data points appear in the analysis.

Although only five totally valid data points are available from this series of tests, the results were sufficiently encouraging to justify formal testing of the same configuration. The maximum bed-material transfer rate obtained during this test series was 26,629 lb/h and required a transport-air flow rate of 128.82 sft³/min and a sparger pressure of 7.3 lb/in²g. The transport ratio for this point is 3.37. These results indicate that this system displayed almost triple the efficiency of the third-generation system and transferred nearly three times the amount of bed material per hour. This maximum bed-material transfer rate was considered to be sufficiently close to the nominal design value of 30,000 lb/h to justify formal testing of this system. In addition, the efficiency of the system (as quantified in the transport ratio) was sufficiently higher than the ERCA cold-modeling value to mandate further study.

As with the other systems tested during the preliminary test series, few meaningful conclusions can be made concerning the controllability and reliability (reproducibility) of the system because of the lack of data on the effect of time between pulses on bed-material transfer rate and the paucity of usable data points for the effect of transport-air flow rate. The only conclusion that can be drawn is that the bed-material transfer rate increases with transport-air flow rate up to the maximum bed-material transfer rate of 26,629 lb/h.

5.1.3 Primary Gasifier-Regenerator Bed-Material Transfer System-- Frequency and Duration Tests

5.1.3.1 Frequency Tests Without Sparger Bleed Air. As stated in Section 5.1.2.4, the preliminary tests N through Y were sufficiently encouraging to justify formal testing. Since reliable control of the bed-material transfer system is of paramount importance, the first test series studied how changes in the pulse frequency (time between pulses) affected the bed-material transfer rate. Results of this testing series are presented in tabular form in Table 4.6 and graphically in Figures 4.10 through 4.12 and 4.25 through 4.27. A review of Table 4.6 indicates that the maximum bed-material transfer rate achieved was 21,240 lb/h. Although this value is somewhat lower than the 26,629 lb/h obtained during the preliminary testing series, it is acceptable. The maximum transport-air flow rate of 92.27 sft³/min is also within an acceptable range, as is the transport ratio. There appears to be a wide variation in the transport ratio (as illustrated in Figure 4.12), but even the low value of 3.81 agrees with previous testing and exceeds ERCA's maximum value.

Although this system would appear to be a viable candidate, major flaws exist in the areas of reliability (reproducibility) and control. The data scatter in bed-material transfer rate versus time between pulses and transport-air flow rate is illustrated in Figures 4.10 and 4.11. With respect to time between pulses, the worst case appears at 12 seconds. At this frequency, the bed-material transfer rate varied between 7,000 and 17,000 lb/h. Since the transport-air flow rate is directly related to the time between pulses, the same variation noted above recurs in Figure 4.11. The quantitative measures of variability and linearity presented in Tables 5.1 through 5.4 indicate that bed-material transfer rate decreases with increasing time between pulses and increases with transport-air flow rate. The data correlation coefficients are respectively -0.85 and +0.74 and will be used as a basis to compare subsequent systems. With respect to linearity, this system's control would be relatively nonlinear, with linear correlation coefficient values of 0.72 and 0.55 for time between pulses and transport-air flow rate respectively.

5.1.3.2 Frequency Tests With Sparger Bleed Air. As stated in Section 3.2.5, sparger pluggage forced a premature conclusion of the frequency tests and necessitated the introduction of bleed air into the Primary Gasifier-Regenerator Bed-Material Transfer System--Fourth Generation. As a result of the bleed-air introduction, the entire series of frequency tests was performed again. Results of this series of tests are presented in Table 4.7 and Figures 4.13 through 4.15 and 4.25 through 4.27. The maximum bed-material transfer rate was again in the 22,000-lb/h range, required approximately 100 to 125 sft³/min of air, and had transport ratios mostly in the range between 3 and 5.

Reliability (reproducibility) and controllability, the major deficiencies of this system prior to introduction of the bleed system were considerably improved in this latter series of tests. Figures 4.13 and 4.14 illustrate the reduction in data scatter for bed-material transfer rate versus time between pulses and transport-air flow rate. At 14.05 seconds, the worst point on the

frequency curve, the variation in bed-material transfer rate is 1,400 lb/h, which compares to a value of 10,000 lb/h for the system prior to the introduction of the bleed air. Once again, the bed-material-transfer-rate-versus-transport-air-flow-rate curve (Figure 4.14) mimics the behavior of the frequency curve, showing considerable reduction in data scatter. The improvement in reliability (reproducibility) and controllability is illustrated quantitatively in Tables 5.1 through 5.4. The data correlation coefficients for time between pulses and transport-air flow rate are -0.94 and +0.81 respectively, indicating an increase of 11 and 10 percent respectively over the same system prior to the introduction of bleed air. The linearity of the system was also improved, exhibiting linear correlation coefficient values of 0.88 and 0.66 for time and transport air respectively. These values represent increases of 22 and 20 percent over the values for the system without bleed air.

5.1.3.3 Duration Tests. Although previous testing suggested that an increase in the pulse on time (time during which transport air was flowing) would be ineffectual in promoting bed-material transfer, two duration tests were performed. Both tests confirmed the futility of increasing pulse on time. The results of these tests are presented in Table 4.7 and Figures 4.13 through 4.15 and 4.25 through 4.27. The results of Test D0 were disturbing, because they did not duplicate the results of Test F2(A), which exhibited ostensibly the same operating conditions. Although the reliability (reproducibility) and controllability of the system had been improved by the introduction of the bleed air, improvements were required before it could be used at La Palma. Even if the values for Test D0 are in error, however, the drastic deterioration in performance caused by an increase in pulse on time is unmistakable. Using the D0 bed-material transfer rate (which is too low), the rate is reduced by 63 percent while using almost the same amount of transport air. In terms of transport ratio, the efficiency of the system plummeted from a value of 3.44 to an unacceptable value of 1.44.

5.1.4 Alternate Gasifier-Regenerator Bed-Material Transfer System Tests

As described in Section 3.3.1, representatives of ERCA and Exxon met at FWEC on June 23, 1976, to observe a demonstration of the Primary Gasifier-Regenerator Bed-Material Transfer System--Fourth Generation. After the demonstration, ERCA/Exxon suggested that the system reliability and controllability should be improved. ERCA and Exxon suggested that this be accomplished by constructing another bed-material transfer system consisting of several 5-in.-diameter circular slots. FWEC agreed to test one circular-slot configuration (Figure 3.7). A summary of the test results for this alternate system is presented in Table 4.8. The results are also presented graphically in Figures 4.16 through 4.18 and 4.25 through 4.27. The test results were very disappointing. Table 4.8 shows that the maximum bed-material transfer rate attained was 2988 lb/h and required 59.24 sft³/min of air. These conditions correspond to a transport ratio (efficiency) of 0.84, which was lower than the unacceptable value of 1.44 obtained during the second duration test (D2). In fact, the highest transport ratio obtained during the alternate tests (1.48) was barely greater than the 1.44 value mentioned above. The only system improvement was a reduction in sparger pressure from ≈ 6.5 to ≈ 3.5 lb/in²g. To

attain the nominal-design bed-material transfer rate of 30,000 lb/h using the alternate design slot configuration, 10 units would have to be used, 592.4 sft³/min of transport air per transfer direction would be used, and more area than is available in the La Palma unit would be required.

The Alternate Bed-Material Transfer System illustrated an acceptable degree of reliability (reproducibility), as can be seen in Figures 4.16 through 4.18 and quantitatively in the standard-deviation values of the dependent variable of Tables 5.1 through 5.4. When controllability of the systems is considered, however, the Alternate Bed-Material Transfer System exhibits a serious deficiency.

The Alternate Bed-Material Transfer System differed significantly from the other systems tested by virtue of its ability to operate in either a pulsing or continuous mode. The values in Table 4.8 and Figures 4.16 through 4.18 demonstrate that system operation was nominally identical for both modes of operation. Controllability in both cases was poor. Figure 4.16 indicates that a sevenfold change in frequency (time between pulses) elicits only, at most, a 730-lb/h change in bed-material transfer rate. The same sevenfold change in frequency for the Primary Gasifier-Regenerator Bed-Material Transfer System--Fourth Generation (with sparger bleed air) produces a 12,900-lb/h change in bed-material transfer rate. With respect to a change in transport-air flow rate, a similar situation exists, as shown in Figure 4.17. The transfer of nominally 2000 to 2500 lb/h of bed material using the Alternate Gasifier-Regenerator Bed-Material Transfer System requires from 25 to 80 sft³/min of transport air. The quantitative measures of correlation and control presented in Tables 5.1 through 5.4 reiterate the decline in performance of this system. The data correlation coefficients are -0.73 and +0.32 for bed-material transfer rate versus time between pulses and transport-air flow rate respectively. These values represent respective reductions of 14 and 57 percent when compared with the values for the Primary Gasifier-Regenerator Bed-Material Transfer System--Fourth Generation (without a sparger bleed air). The linearity parameters of Table 5.4 indicate a poor linear fit for bed-material transfer rate versus time between pulses and a very poor linear correlation coefficient for bed-material transfer versus transport-air flow rate. The very low values of the slope quantitatively demonstrate the poor control available with this system. A wide variation in the independent variable elicits only a small response in the dependent variable.

5.1.5 Final Gasifier-Regenerator Bed-Material Transfer System Tests

5.1.5.1 Perforated-Plate-Sparger Tests. After an unsuccessful attempt to develop a modified version of the alternate gasifier-regenerator bed-material transfer slot that would operate as desired (see Section 3.3.2 for description), it was decided that an attempt would be made in the final weeks available for testing to develop a new Gasifier-Regenerator Bed-Material Transfer System that would meet all system requirements.

Drawing upon the previous testing experience on all slot configurations, the design depicted in Figure 3.9 was developed and tested. A summary of the

test results appears in Table 4.9 and in Figures 4.19 through 4.21 and 4.25 through 4.27. The maximum bed-material transfer rate attained was approximately 20,000 lb/h, which is almost equal numerically to the 22,000 lb/h obtained during the Primary Gasifier-Regenerator Bed-Material Transfer System (with sparger bleed air) tests. Since the latter tests were the most promising to this point, these results were very encouraging. The 20,000-lb/h bed-material transfer rate was even more impressive considering that the new bed-material transfer slot occupies only 25 percent of the space required by the other transfer slot. Two of the new bed-material transfer slots could transfer 40,000 lb/h of bed material in one direction (which exceeds the nominal design value of 30,000 lb/h by 25 percent) while using only 50 percent of the space required by the other slot. A comparison of transport-air-usage figures once again demonstrates the clear advantage of the Final Gasifier-Regenerator Bed-Material Transfer System design. The final design transferred 20,080 lb/h of bed material using 36.54 sft³/min of air. The primary gasifier-regenerator bed-material transfer slot design (with sparger bleed air) required between 100 and 125 sft³/min to transfer approximately the same amount of bed material. Although data scatter in the latter system makes an exact comparison difficult, the Final System uses at least two to three times less transport air. This ratio appears again if the transport ratios are compared. Another advantage of the Final Transfer System was a reduction in sparger pressure from a value of 6 to 7 lb/in²g to a more reasonable value of 3 to 4 lb/in²g.

Reliability (reproducibility) and controllability were considerably better than those observed during the testing of the other candidate bed-material transfer systems. Figures 4.19 and 4.20 illustrate the reduction in data scatter for bed-material transfer rate versus time between pulses and transport-air flow rate. The improvement is indicated quantitatively in Tables 5.1 through 5.4. For example, the data correlation coefficients for time between pulses and transport-air flow rate are -0.99 and -0.92 respectively. These values correspond to increases of 17 and 24 percent respectively over the base comparison system (Primary Gasifier-Regenerator Bed-Material Transfer System--Fourth Generation without sparger bleed air). The increases over the Primary System with sparger bleed air were 5 and 14 percent respectively. The linear correlation coefficients for the Final System were also considerably higher than those for the Primary System with and without sparger bleed air. The bed-material transfer rate versus time between pulses linear correlation coefficient values for each system were 0.72 (Primary), 0.88 (Alternate), and 0.99 (Final). The Final System value represents a very high degree of linearity between the variables. For bed-material transfer rate versus transport-air flow rate, the linear correlation coefficients are 0.55 (Primary), 0.66 (Alternate), and 0.88 (Final).

5.1.5.2 Three-Tube Sparger Tests. As described in Section 3.4.1, a sparger pluggage problem developed with the Final Gasifier-Regenerator Bed-Material Transfer System when the perforated-plate sparger was used. A three-tube sparger replaced the perforated-plate sparger (see description in Section 3.4.2). This modified system operated even more ideally than the original configuration, and the test results appear in Table 4.10 and Figures 4.22 through 4.27. The system transferred approximately 20,000 lb/h (the

same as with the other sparger) but used approximately 34 percent more air (48.82 sft³/min). This value is, nevertheless, quite acceptable. Although the average value of the transport ratio was slightly lower for the modified system (7.38 versus 7.82), the ability of this system to operate at a 2.5-lb/in²g sparger pressure more than compensated for the slightly higher transport-air usage.

One particular point of interest occurred in Test LS-8, in which the system was run in a continuous rather than pulsing mode. The deterioration in system performance was immediately evident. Operating continuously, the system required nearly four times the amount of transport air required under pulsing conditions to transfer the same amount of bed material. This effect is quantitatively reflected in the fourfold decrease in transport ratio shown in Table 4.10 and Figure 4.24.

With respect to reliability (reproducibility) and controllability, the modified version of the Final Gasifier-Regenerator Bed-Material Transfer System (incorporating the three-tube sparger) was nominally the same as the system using the perforated-plate sparger. The quantitative measures of data scatter and linearity (Tables 5.1 through 5.4) demonstrate the close correspondence of both systems. The data correlation coefficients for bed-material transfer rate versus time between pulses are respectively -0.98 and -0.99 for the three-tube and perforated-plate versions of the Final System. These values are essentially identical. The data correlation coefficients for bed-material transfer rate versus transport-air flow rate are 0.92 for the three-tube version and 0.98 for the perforated-plate version, indicating a 7 percent improvement for the three-tube sparger system.

The quantitative measures of linearity (the linear correlation coefficients) demonstrate the same trends as the measures of data scatter (data correlation coefficients) did. For bed-material transfer rate versus time between pulses, the linear correlation coefficients are essentially identical for the three-tube and perforated-plate versions of the Final System (0.99 and 0.97 respectively). Again, the bed-material transfer rate versus transport-air flow rate coefficients indicate a nominal improvement of approximately 12 percent for the three-tube sparger system.

5.1.6 Combined Results

In an effort to present a clear picture of the relative performance of each of the Gasifier-Regenerator Bed-Material Transfer Systems tested, Figures 4.25 through 4.27 were constructed. By eliminating questionable points and coalescing repeated points by means of averaging, data trends became obvious and could be depicted for all data sets on a single graph.

Figure 4.25 shows the increase in controllability (linearity) as the Final Gasifier-Regenerator Bed-Material Transfer System was developed. An improvement not clearly demonstrated in the individual graphs is the increased controllability range of the Final System using the three-tube sparger, compared to the same system using the perforated-plate sparger. This improvement

is quantitatively presented in Table 5.4 as a reduction in the slope of the linear least-squares curve fit line.

The dramatic reduction in transport-air consumption is illustrated in Figure 4.26. The rate of increase in bed-material transfer rate caused by an increase in transport-air flow rate is also presented in Figure 4.26. The final systems illustrate a much higher rate of increase than the other systems, indirectly demonstrating the improved efficiencies of the later systems.

Figure 4.27 graphically compares the transport ratios (efficiencies) of the various systems and shows the variation of efficiency with bed-material transfer rate. Once again, the Final Gasifier-Regenerator Bed-Material Transfer System demonstrated the most consistently high values of transport ratio of any of the systems tested.

5.2 QUALITATIVE RESULTS

As stated in Section 4.8, qualitative results (in the form of a 16-mm movie) were obtained for the major slot geometries tested. The film offers a comparison of the primary gasifier-regenerator bed-material transfer slot--fourth generation, the alternate gasifier-regenerator bed-material transfer slot, and the final gasifier-regenerator bed-material transfer slot using the three-tube sparger.

The primary information obtained from the film relates to the gas leakage into the "supply" bed. A review of the film indicates a high level of air leakage back into the "supply" bed for the Primary Gasifier-Regenerator Bed-Material Transfer System. In fact, for this system air leakage even occurs between pulses. Little or no gas leakage is evident for both the Alternate and Final Gasifier-Regenerator Bed-Material Transfer Systems. For the Final System, the gas leakage appeared to be related to the bed-material transfer rate, with an increase in air leakage corresponding to a higher bed-material transfer rate. This trend is reflected in the decline in transport ratio as the bed-material transfer rate approaches 20,000 lb/h (see Figure 4.24). Nevertheless, the air leakage for the Final System, even at the extreme bed-material transfer rate point, is low.

Section 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The Gasifier-Regenerator Bed-Material Transfer System selected for La Palma should most closely approximate the optimum bed-material transfer system specification presented in Section 5.1.1. Specifically, the selected system should exhibit the highest bed-material transfer rate using the smallest amount of transport gas and the lowest sparger pressure. In addition, the system should allow only minimal air leakage back into the "supply" bed and maintain a high level of controllability and reliability. Of all the systems tested, the Final Gasifier-Regenerator Bed-Material Transfer System using the three-tube sparger most closely approximates the optimum system.

The actual system choices are not as extensive as previous results might indicate, since the systems that exhibited sparger plugging should be removed from consideration. Under these conditions, the system choices narrow to three: the Primary (with sparger bleed air), Alternate, and Final (with three-tube sparger) Gasifier-Regenerator Bed-Material Transfer Systems. For the system comparison to be valid, all system results should be compared using an equivalent basis. The basis chosen is an equal length requirement along the division wall. With reference to Figures 3.6, 3.7, and 3.11, all units will be adjusted to a 24-in.-equivalent slot length. With this basis, the maximum bed-material transfer rates for the Primary, Alternate, and Final Systems become respectively 22,000, 14,342, and 80,000 lb/h. It is obvious that the Final System transfers the most material. The transport-air usage values for each of these flow rates (using proportionate values from the actual data) would be 113 (Primary), 284 (Alternate), and 195 (Final) sft³/min. These total air usage values are misleading, and a much truer picture appears when the air usage figures are presented on a per-1000-lb-of-bed-material-transferred basis. The appropriate values for each system are 5.14 (Primary), 19.80 (Alternate), and 2.44 (Final). To transfer the nominal bed-material-transfer design rate of 30,000 lb/h in each direction would require:

- $2 \times 30,000 \times (5.14/1000) = 308.4 \text{ sft}^3/\text{min}$ for the Primary System
- $2 \times 30,000 \times (19.80/1000) = 1188.0 \text{ sft}^3/\text{min}$ for the Alternate System
- $2 \times 30,000 \times (2.44/1000) = 146.4 \text{ sft}^3/\text{min}$ for the Final System.

Here again, the Final System is clearly superior.

The third comparison point between the actual and ideal systems is sparger pressure. From the data summaries, appropriate sparger-pressure values for the Primary, Alternate, and Final Gasifier-Regenerator Bed-Material Transfer Systems are 6.5, 3.5, and 2.5 lb/in²g respectively. The Final System operates at the lowest sparger pressure and is therefore superior. With respect to air leakage back into the "supply" bed, a review of the film indicates that the Alternate System was the best, the Primary System the worst, and the Final System better than average.

The final criterion set forth in Section 5.1.1 for the optimum bed-material transfer system was that it maintain a high level of controllability and reliability (reproducibility). The relative measures of controllability and reliability are the linear and data correlation coefficients presented in Tables 5.1 through 5.4. With respect to the linearity of the bed-material transfer rate versus time between pulses and transport-air flow rate, the linear correlation coefficients for the Primary, Alternate, and Final Systems are 0.88, 0.53, 0.97 (time) and 0.66, 0.11, and 0.95 (air) respectively. Since a value of 1.0 denotes complete linearity, the Final System is definitely the most linear. A consideration of the data scatter as represented in the data correlation coefficients again demonstrates the superiority of the Final System. For bed-material transfer rate versus time between pulses, the data correlation coefficients are -0.94, -0.73, and -0.98 for the Primary, Alternate, and Final Systems respectively. For bed-material transfer rate versus transport-air flow rate, the corresponding values are +0.81, 0.32, and 0.98. Since a value of ± 1.0 indicates complete correlation, the Final System is the most reproducible. When all the aforesaid comparisons are considered together, the Final System clearly emerges as the best. As stated previously, of all the systems tested, the Final Gasifier-Regenerator Bed-Material Transfer System using the three-tube sparger most closely approximates the optimum system.

6.2 RECOMMENDATIONS

Based on the testing information (presented in previous sections), the Final Gasifier-Regenerator Bed-Material Transfer System using the three-tube sparger was recommended as the preferred design for use at La Palma. As stated in Section 3.4.2, the system geometry basic design parameters and operating conditions were transmitted to the FWEC Contract Design Department for inclusion in the gasifier-regenerator drawings. A pictorial representation of the Final System as it will appear in the gasifier and regenerator is presented in Figure 3.12. As indicated in Section 3.4.2, a total of four transfer slots (two in each direction) are required to transfer 40,000 lb/h of bed material. In addition, to provide greater flexibility and reliability, individual sparger manifolds were used, requiring that the transfer slots be vertically offset by 3-in. from each other. Extra air/flue gas nozzles were positioned at the slot exits to increase fluidization and enhance bed-material transfer. Despite these minor variations, the basic design is that of the bed-material transfer slot which performed so well in the cold-model tests and which, of all the systems tested, most closely approximates the optimum system.

Section 7

REFERENCES

1. J. W. T. Craig, et al., "Study of Chemically Active Fluid-Bed Gasifier for Reduction of Sulphur Oxide Emissions," Esso Research Centre, final report prepared for U.S. Environmental Protection Agency, Report No. PB 211 438, EPA-650/2-74-109, Contract No. 68-02-0300, June 1972.
2. J. A. Bazan, "Notes of Meeting," September 3, 1975.
3. J. W. T. Craig, et al., "Study of Chemically Active Fluid Bed Gasifier for Reduction of Sulphur Oxide Emissions," Esso Research Centre, interim report, Report No. PB 202 221, APCO Contract CPA 70-46, February 22, 1971.
4. J. W. T. Craig, et al., "Chemically Active Fluid-Bed Process for Sulphur Removal During Gasification of Heavy Fuel Oil--Second Phase," Esso Research Centre, prepared for U.S. Environmental Protection Agency, Report No. PB 240 632, EPA-650/2-74-109, Contract No. 68-02-0300, November 1974.

APPENDIX A
FLOW MEASUREMENT SYSTEM USED IN 36-FT² FLUIDIZED-BED
COLD MODEL--FLUIDIZED-BED STEAM GENERATOR TESTING

Appendix A

FLOW MEASUREMENT SYSTEM USED IN 36-ft² FLUIDIZED-BED COLD MODEL--- FLUIDIZED-BED STEAM GENERATOR TESTING

The pitot tube air flow-rate measuring system originally specified for use with the 36-ft² fluidized-bed cold model was found to be unusable. Because of limitations of space availability and the size of the required ducts (to minimize noise pollution), two close 180-degree bends were required prior to the straight-measuring section of the inlet duct. As a result, an erratic velocity profile developed within the duct with swirling eddies predominant. The pitot tube pressure differential readings fluctuated in resonance with the changing velocity profile, and the magnitude of the fluctuations was such that the information obtained was rendered useless.

Since modification of the inlet duct would have been an expensive and time-consuming operation, an alternate method of measuring air flow rate was explored. The least expensive and most easily implemented modification was to correlate flow rate through the fluidized-bed steam generator cold-model testing perforated-plate air distributor (as obtained from pressure-drop readings across the plate and a calibration using a small cold model) versus amperage (horsepower). Amperage readings could then be used to determine flow rate under other test conditions (e.g., with a bed present, etc.). This correlation was obtained and was found to be sufficiently accurate for the tests performed. The development of the correlation will be traced in the following paragraphs so that its utility and limitations may be understood.

A section of the fluidized-bed steam generator cold-model testing perforated plate was tested using the small cold model. Plate-pressure-drop-versus-flow-rate data were recorded and reduced and are presented in graphical form in Figure A.1.

To use these data for predicting the plate-pressure-loss-versus-flow-rate relationship in the 36-ft² model, an equation of the following form was assumed:

$$\Delta P(\text{Plate}) = \frac{K_f (\dot{m})^2 (27.7)}{(3600)^2 (2) [g_c] (144) [\rho_g] [A_F]^2} \quad (1)$$

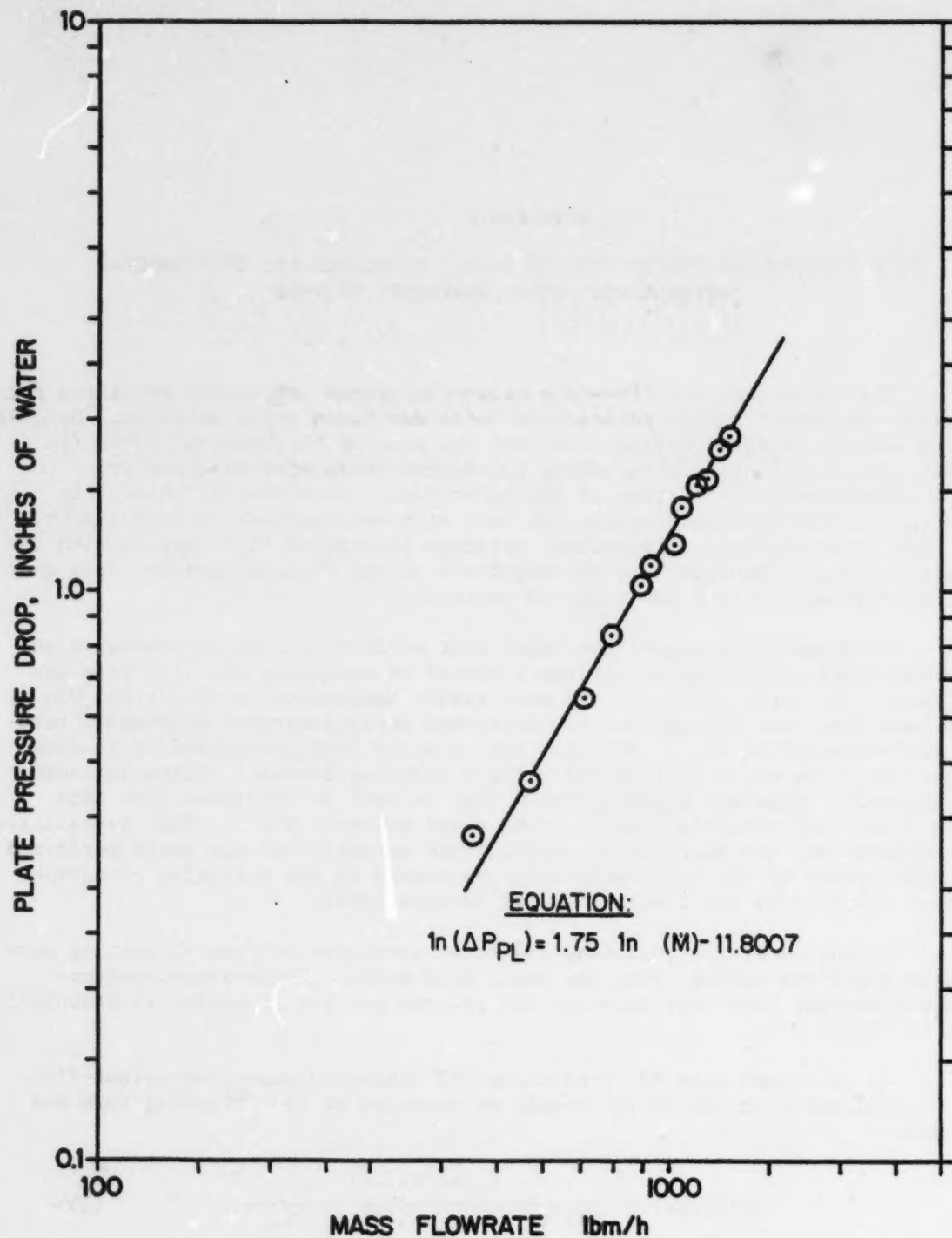


Figure A.1 Perforated-Plate Pressure Drop vs. Mass Flow Rate (small model test)

The percentage of free area of the fluidized-bed steam generator cold-model testing perforated plate as received was 7.55 percent, and the flow area for the small model was 99.75 in²; therefore, the free area, A_F, equaled 0.0523 ft². By substituting into Equation (1), reducing, and solving for the flow coefficient, K_f, the following equation was obtained:

$$K_f = \frac{(1.1858 \times 10^7)(\Delta P(\text{Plate}))(\rho_g)}{\dot{m}^2} \quad (2)$$

Following the work of Smith and Van Winkle,* a Reynolds number based on the hole diameter of the perforated plate can be defined as follows:

$$Re_h = \frac{(\dot{m})(d_h)}{(3600)(A_F)(\mu)(6.72 \times 10^{-6})} \quad (3)$$

Using Equations (2) and (3) and the plate pressure drop/flow rate data from the small model test, a graph of K_f as a function of Re_h was obtained. This graph is presented as Figure A.2.

The perforated plate was installed within the 36-ft² model and the free area was measured. Taking into account flow blockages caused by the support system in the 36-ft² model, the percentage of free area was reduced to 6.78 percent and the actual free area was 2.44 ft².

Solving Equation (1) for $\dot{m}$ yields:

$$\dot{m} = \frac{(160,658)(\rho_g)^{1/2}(\Delta P(\text{Plate}))^{1/2}}{(K_f)^{1/2}} \quad (4)$$

Solving Equation (3) for $\dot{m}$ yields:

$$\dot{m} = 1133(\mu)(Re_h) \quad (5)$$

*P. L. Smith, Jr. and M. Van Winkle, "Discharge Coefficients Through Perforated Plates at Reynolds Numbers of 400 to 3,000," AIChE Journal, Vol. 4, No. 3, September 1958, pp. 266-268.

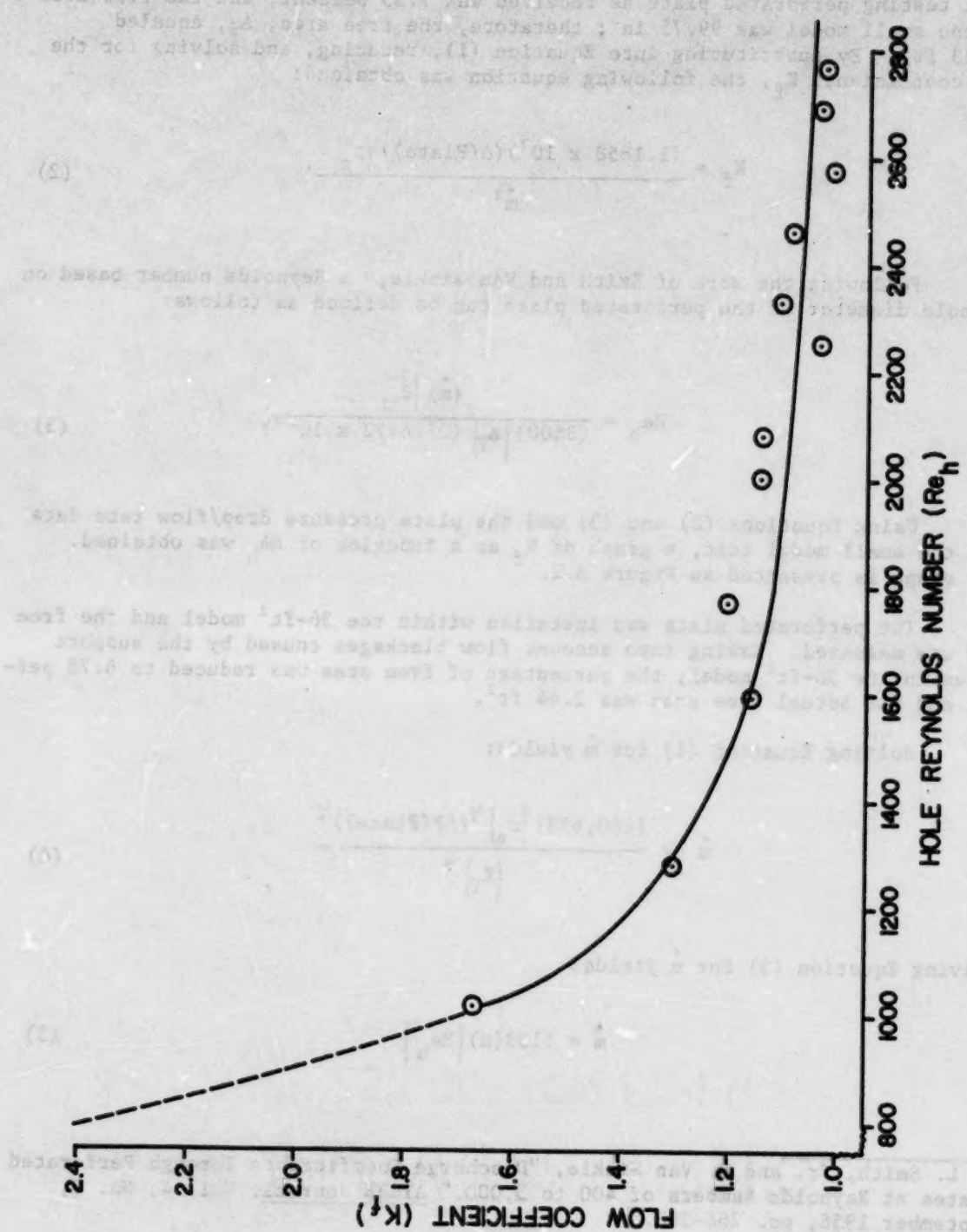


Figure A.2 Perforated-Plate Flow Coefficient as a Function of Reynolds Number (small model test)

The value of viscosity (μ) in centipoise is calculated as a function of temperature by the Sutherland equation,* which reduces for air to the following equation:

$$\mu = \frac{(6.08642 \times 10^{-4})(T)^{3/2}}{[0.555(T) + 120]} \quad (6)$$

Using temperature, density, and pressure data from the large model, mass flow rate is calculated by the following procedure:

1. A value of the hole Reynolds number (Re_h) is assumed.
2. The mass flow rate is calculated from Equation (5).
3. From the small model data graph of K_f vs. Re_h , a value of K_f corresponding to the assumed Re_h is obtained.
4. The mass flow rate is calculated from Equation (4).
5. Mass flow-rate values from steps (2) and (3) above are compared and steps (1) through (5) repeated until the values agree.

Amperage values corresponding to the calculated mass flow rates were also recorded as data points. Four sets of data were generated for a total of 27 data points. Mass flow rate as a function of amperage was plotted and the function appeared to be linear. A first-order least-squares regression was made and the resultant equation plotted on the same sheet as the data points. This plot appears in Figure A.3. Mass flow rates for all tests were obtained from amperage readings by applying the least-squares regression equation appearing in Figure A.3.

*Crane Company, "Flow of Fluids Through Valves, Fittings, and Pipe," Technical Paper No. 410, 1957, p. A5.

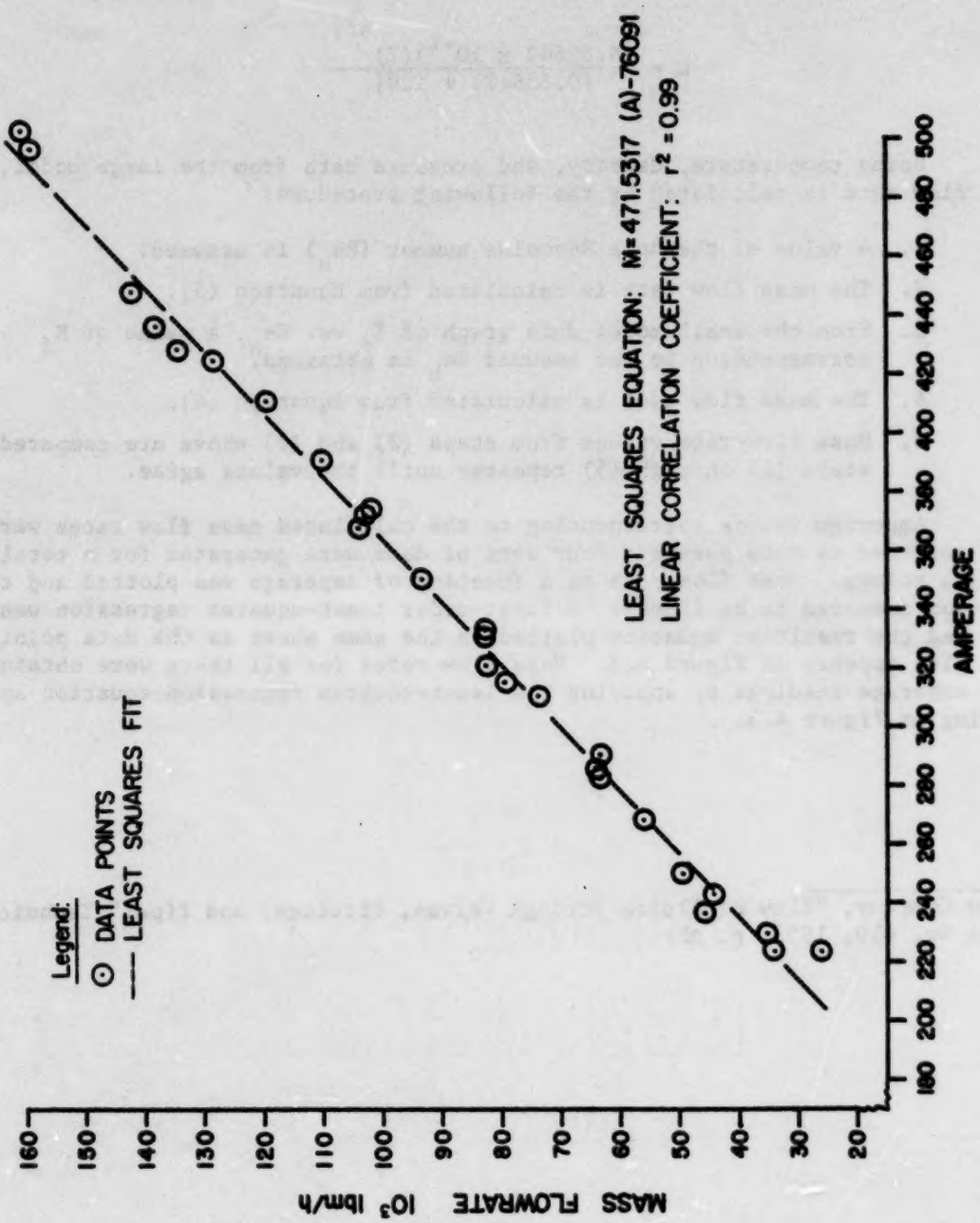


Figure A.3 Mass Flow Rate vs. Amperage (large cold model)

APPENDIX B
COMPARISON OF MEASUREMENT SYSTEMS FOR BED-MATERIAL
TRANSFER SYSTEM

Appendix B

COMPARISON OF MEASUREMENT SYSTEMS FOR BED-MATERIAL TRANSFER SYSTEM

INTRODUCTION

As stated in Section 3.1.2 of the text, two bed-material transfer-measurement systems were considered for use in the cold-model simulation of the CAFB demonstration-plant bed-material transfer system. The first system, which was used by ERCA in its cold-modeling work, utilized the analogy between heat and mass transfer to calculate the bed-material transfer rate from temperature measurements. The second system, which FWEC has used, utilized load beams to transform the air-distribution plates in both the gasifier and regenerator into weighbridges. This system directly measures the bed-material transfer rate as a change of weight over a time period. A full comparison of both systems, including descriptions, derivations of equations, error analysis, and cost comparison will be made in this appendix.

DESCRIPTION OF SYSTEMS

Heat/Mass Transfer Analogy System

The first system to be considered is that which utilizes the analogy between heat and mass transfer to determine the bed-material transfer rate. A schematic of the overall gasifier and regenerator system appears in Figure B.1. An overall energy balance around the system (dotted line in Figure B.1) yields:

$$\Delta KE + \Delta PE + \Delta H = -QL_G - QL_R. \quad (7)$$

where:

- ΔKE = Change in kinetic energy = $KE_3 + KE_4 - KE_1 - KE_2$
- ΔPE = Change in potential energy = $PE_3 + PE_4 - PE_1 - PE_2$
- ΔH = Change in enthalpy = $\Delta H_3 + \Delta H_4 - \Delta H_1 - \Delta H_2$
- QL_G and QL_R = Heat losses.

*Subscript numbers 1 through 4 refer to boundaries established in Figure B.1.

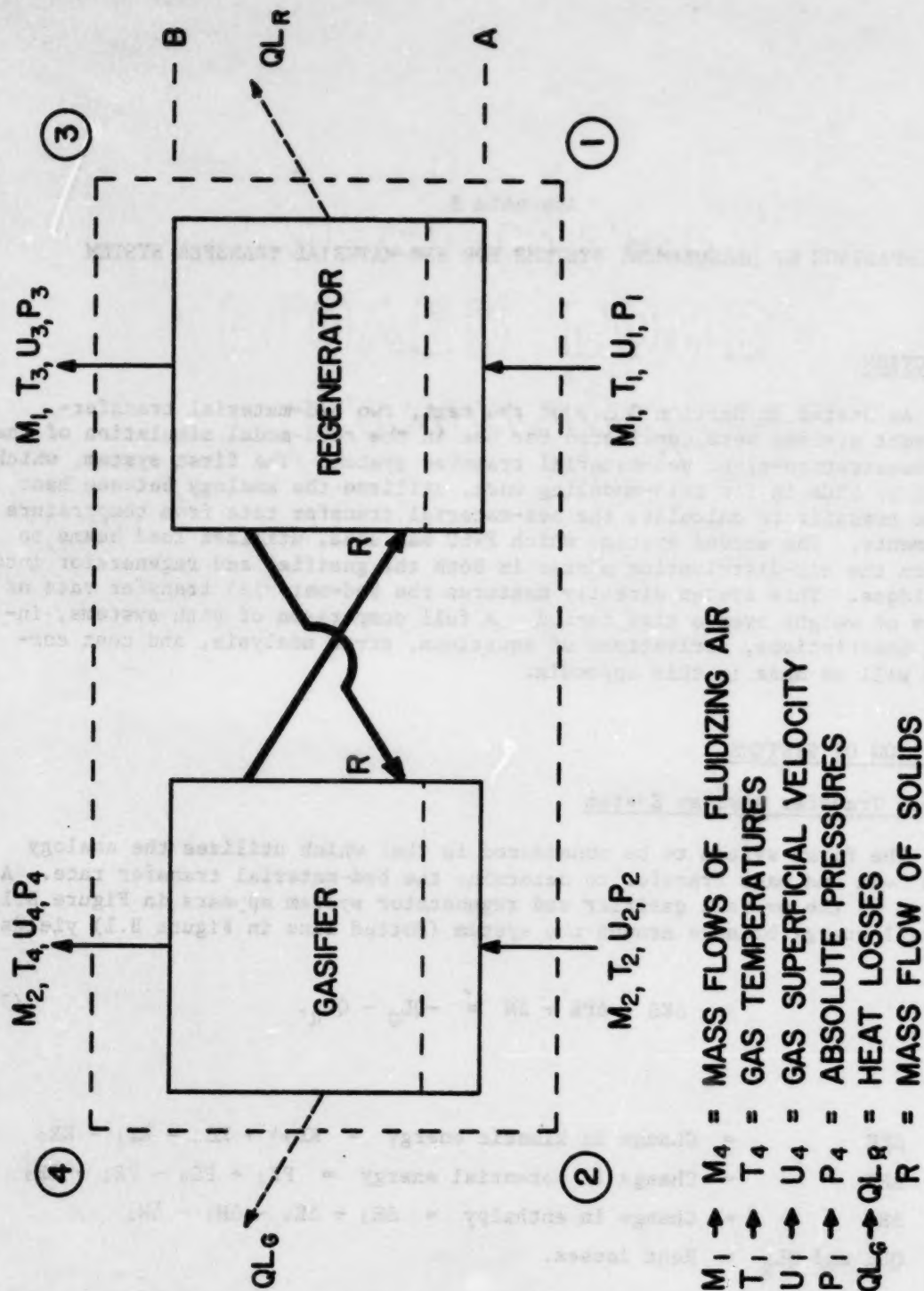


Figure B.1 CAFB Cold Modeling--Overall System Schematic

With the assumption that air is an ideal gas at operating conditions and the definitions of kinetic and potential energy, the following substitutions can be made in Equation (7):

$$KE = \frac{MU^2}{2 g_c J}; PE = \frac{MZg}{g_c J}; \Delta H = (Mc_{pg} T - T_o).$$

where:

- g_c = Newton's law conversion factor = 32.174 ft·lb/lb·s²
- g = Acceleration of gravity = 32.2 ft/s²
- J = Mechanical equivalent of heat = 778.28 Btu/ft·lb
- Z = Distance above reference level (ft)
- T_o = Reference temperature (°R)
- c_{pg} = Mean specific heat of gas (Btu/lb·°R).

Applying these substitutions to Equation (7) and simplifying, we obtain:

$$M_1 \left[\frac{U_3^2 - U_1^2}{2 g_c J} + \frac{g}{g_c J} (Z_B - Z_A) + c_{pg} (T_3 - T_1) \right] + M_2 \left[\frac{U_4^2 - U_2^2}{2 g_c J} + \frac{g}{g_c J} (Z_B - Z_A) + c_{pg} (T_4 - T_2) \right] = -QL_G - QL_R. \quad (8)$$

An energy balance around the gasifier yields:

$$\Delta KE_{4-2} + \Delta PE_{4-2} + \Delta H_{4-2} + R c_{ps} (T_4 - T_3) = -QL_G \quad (9)$$

which, upon substitution as before, yields:

$$M_2 \left[\frac{U_4^2 - U_2^2}{2 g_c J} + \frac{g}{g_c J} (Z_B - Z_A) + c_{pg} (T_4 - T_3) + R c_{ps} (T_4 - T_3) \right] = -QL_G. \quad (10)$$

Solving for R yields:

$$R = \frac{QL_G}{c_{ps} (T_3 - T_4)} - \frac{M_2}{c_{ps} (T_3 - T_4)} \left[\frac{U_4^2 - U_2^2}{2 g_c J} + \frac{g}{g_c J} (Z_B - Z_A) + c_{pg} (T_2 - T_4) \right]. \quad (11)$$

Similarly, an energy balance around the regenerator yields:

$$M_1 \left[\frac{U_3^2 - U_1^2}{2 g_c J} + \frac{g}{g_c J} (Z_B - Z_A) + c_{pg} (T_3 - T_1) \right] + R c_{ps} (T_3 - T_4) = -Q_{L_R} \quad (12)$$

$$R = \frac{M_1}{c_{ps} (T_3 - T_4)} \left[\frac{U_3^2 - U_1^2}{2 g_c J} + \frac{g}{g_c J} (Z_B - Z_A) + c_{pg} (T_1 - T_3) \right] - \frac{Q_{L_R}}{c_{ps} (T_3 - T_4)} \quad (13)$$

Equations 11 and 13 can be simplified if the kinetic energy, potential energy, and enthalpy terms are compared by order of magnitude as follows:

U_1 is assumed equal to 6 ft/s, and a temperature change of 20°F and a pressure change of 70 in. H_2O is assumed:

$$U_3 = U_1 \left(\frac{T_3}{T_1} \frac{P_1}{P_3} \right) = 6 \left(\frac{580}{560} \right) \left(\frac{17.23}{14.7} \right) = 7.28 \text{ ft/s}$$

$$\therefore \frac{U_3^2 - U_1^2}{2 g_c J} = \frac{7.28^2 - 6.00^2}{(2)(32.174)(778)} = 0.00034 \text{ Btu/lb} \quad (A)$$

If $Z_B - Z_A = 30 \text{ ft}$,

$$\frac{g}{g_c J} (Z_B - Z_A) = \frac{(32.2)(30)}{(32.174)(778)} = 0.03859 \text{ Btu/lb.} \quad (B)$$

The c_{pg} of air over the range of 100 to 200°F = 0.24 Btu/lb·°F:

$$c_{pg} (T_3 - T_1) = 0.24(20) = 4.80 \text{ Btu/lb} \quad (C)$$

Term (C) is over 14,000 times larger than Term (A) and over 124 times larger than Term (B). Both kinetic-energy and potential-energy contributions can safely be ignored with a maximum error of less than 1 percent in the value of the term in brackets in Equations (11) and (13).

Applying the results described above, Equations (11) and (13) can be rewritten as follows:

$$R = \frac{QL_G}{c_{ps}(T_3 - T_4)} - \frac{M_2 c_{pg}(T_2 - T_4)}{c_{ps}(T_3 - T_4)} \quad (14)$$

and

$$R = \frac{M_2 c_{pg}(T_1 - T_3)}{c_{ps}(T_3 - T_4)} - \frac{QL_R}{c_{ps}(T_3 - T_4)} \quad (15)$$

In a similar manner, Equation (8) now becomes:

$$M_1 c_{pg}(T_3 - T_1) + M_2 c_{pg}(T_4 - T_2) = -QL_G - QL_R \quad (16)$$

If the gasifier and regenerator are operated under the following conditions, the heat-loss term can be evaluated:

$$M = M_1 = M_2$$

$$T_3 = T_4$$

$$T_1 = T_2$$

$$QL = QL_G = QL_R$$

Equation (16) becomes:

$$Mc_{pg}(T_3 - T_1) = -QL \quad (17)$$

The heat loss can be expressed by the convection equation:

$$QL = UA(T_3 - T_A) \quad (18)$$

where:

QL = Heat loss

UA = Heat-transfer constant for external walls

T_A = Ambient temperature.

Equation (16) becomes:

$$Mc_{pg}T_1 = Mc_{pg}T_3 + UA(T_3 - T_A). \quad (19)$$

Measurement of M , T_1 , T_3 , and T_A will allow the value of UA to be determined. This value will be constant for all other operating conditions.

The bed transfer rate, R , can be determined from Equations (14) and (15) and the previously determined value of UA by inducing a temperature difference between T_1 and T_2 . This temperature difference can be attained by heating the air to the regenerator approximately 20°F higher than that to the gasifier.

Weighbridge System

The second system considered utilizes load beams to transform the air-distributor plates in both the gasifier and regenerator into weighbridges. The arrangement, as shown in Figure B.2, is very similar to that used by BLH Electronics (Waltham, Massachusetts) in the construction of its electronic weighbridge scales, but the application to fluid beds is quite unique. This system would directly measure the bed-material transfer rate (in one direction) as a change of weight over a time period.

ERROR ANALYSIS

Heat/Mass Transfer Analogy System

In the heat/mass transfer analogy system, Equation (14) or (15) can be used to calculate the bed transfer rate, provided UA has been previously determined. To simplify error analysis, it will be assumed that the heat loss, QL , is negligible. Under this restriction, Equation (14) becomes

$$R = \frac{-M_2 c_{pg} (T_2 - T_4)}{c_{ps} (T_3 - T_4)}. \quad (20)$$

As can be seen from Equation (20), R will be sensitive to the air-mass flow rate, M_2 , and the temperature differences $(T_2 - T_4)$ and $(T_3 - T_4)$. It will be necessary to determine temperatures and the air-mass flow rate very accurately to ensure reasonable accuracy in determining R . A simple example will be evaluated to indicate the accuracy required.

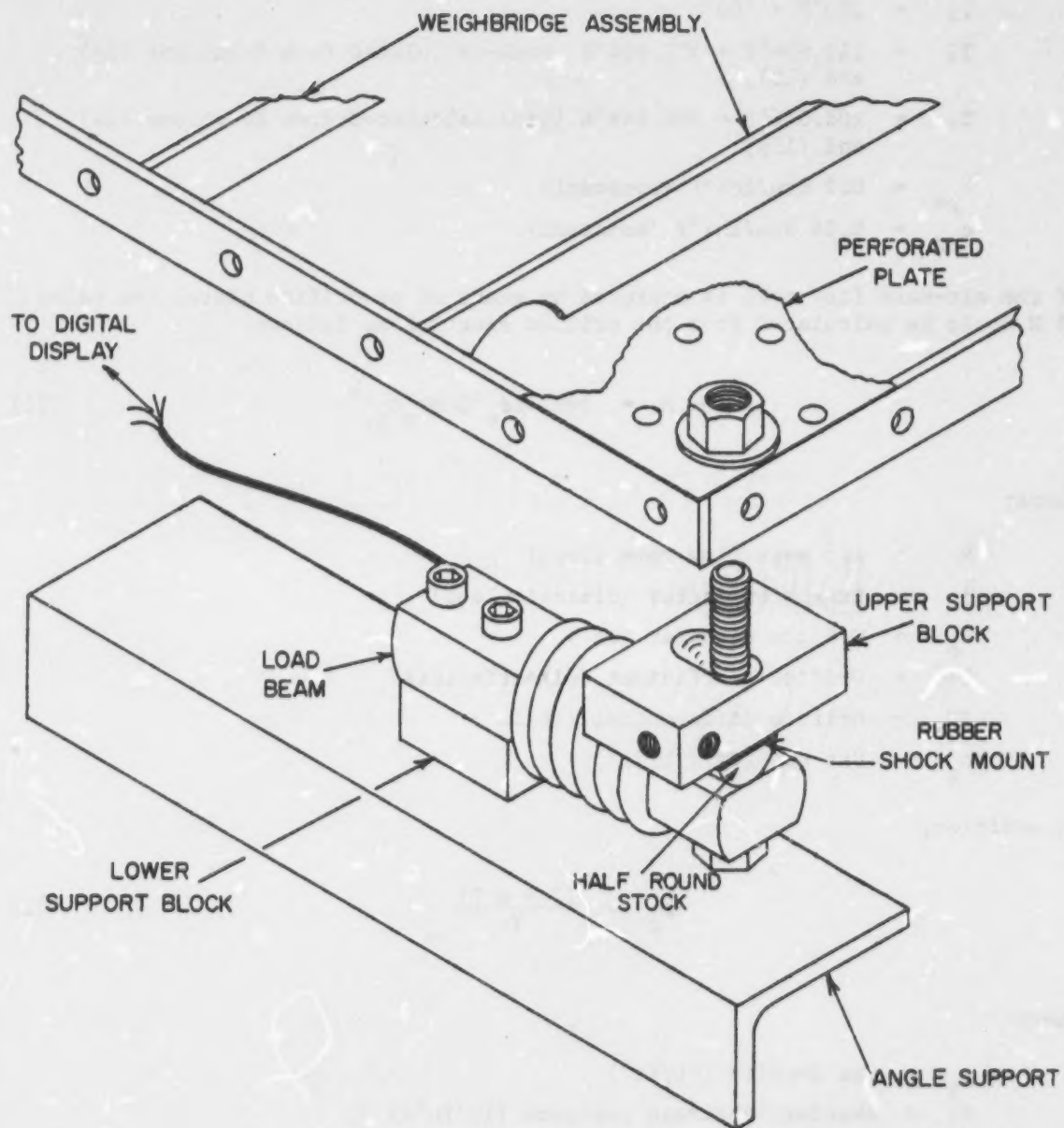


Figure B.2 CAFB Cold Modeling--Weighbridge System Typical Assembly

The assumed conditions are:

- $T_1 = 120^\circ\text{F} = 580^\circ\text{R}$
- $T_2 = 100^\circ\text{F} = 560^\circ\text{R}$
- $T_3 = 111.954^\circ\text{F} = 571.954^\circ\text{R}$ [back-calculated from Equations (14) and (15)]
- $T_4 = 108.046^\circ\text{F} = 568.046^\circ\text{R}$ [back-calculated from Equations (14) and (15)]
- $c_{ps} = 0.2 \text{ Btu/lb}\cdot^\circ\text{F}$ (constant)
- $c_{pg} = 0.24 \text{ Btu/lb}\cdot^\circ\text{F}$ (constant).

If the air-mass flow rate is measured by means of an orifice plate, the value of M would be calculated from the orifice equation as follows:

$$M = 1891 Y d_o^2 C (\Delta P_o \rho_g)^{1/2} \quad (21)$$

where:

- M = Air-mass flow rate (lb/h)
- Y = Expansion factor (dimensionless)
- d_o = Orifice diameter (in.)
- C = Orifice coefficient (dimensionless)
- ΔP_o = Orifice differential (lb/in²)
- ρ_g = Gas density (lb/ft³).

In addition,

$$\rho_g = \frac{(2.7 \times P)}{T_1} \quad (22)$$

where:

- ρ_g = Gas density (lb/ft³)
- P_1 = Absolute upstream pressure (lb/in²a)
- T_1 = Absolute temperature ($^\circ\text{R}$).

The assumed conditions are:

- $P_1 = 17.23 \text{ lb/in}^2\text{a}$
- $T_1 = 560^\circ\text{R}$

$$\begin{aligned}
 Y &= 1.0 \\
 d_o &= 2.793 \text{ in.} \\
 C &= 0.605 \\
 M &= 13,353 \text{ lb/h.}
 \end{aligned}$$

The values of gas density and orifice differential are calculated from Equations (21) and (22) as:

$$\rho_g = \frac{2.7(17.23)}{560} = 0.08306 \text{ lb/ft}^3$$

and

$$\Delta p_o = 26.95 \text{ in. H}_2\text{O.}$$

If the following errors are assumed:

$$\begin{aligned}
 \text{Temperature} &- \pm 1^\circ\text{F} \\
 \text{Pressure} &- \pm 0.1 \text{ lb/in}^2 \\
 \text{Orifice differential} &- \pm 0.2 \text{ in. H}_2\text{O}
 \end{aligned}$$

the values of gas density in lb/ft^3 are as in the following matrix:

<u>Temperature ($^\circ\text{R}$)</u>	<u>Pressure (lb/in^2)</u>		
	<u>17.13</u>	<u>17.23</u>	<u>17.33</u>
559	0.08274	0.08322	0.08370
560	0.08259	0.08307	0.08356
561	0.08244	0.08293	0.08341

Using the minimum, average, and maximum values of gas density and of orifice differential pressure, the following values of air-mass flow in lb/h are obtained:

<u>Gas Density (lb/ft^3)</u>	<u>Orifice Differential Pressure (in. H_2O)</u>		
	<u>26.75</u>	<u>26.95</u>	<u>27.05</u>
0.08244	13,253	13,302	13,327
0.08307	13,303	13,353	13,378
0.08370	13,354	13,403	13,428

Assuming a 0.1°F error in the measurement of all temperatures, the values of inlet and outlet temperatures become:

$$T_1 = 580 \pm 0.1^\circ\text{R}$$

$$T_2 = 560 \pm 0.1^\circ\text{R}$$

$$T_3 = 571.954 \pm 0.1^\circ\text{R}$$

$$T_4 = 568.046 \pm 0.1^\circ\text{R}.$$

From these values, the values of the required temperature differences are:

$$(T_3 - T_4) = 3.908 \pm 0.2$$

$$(T_2 - T_4) = 8.046 \pm 0.2$$

and

$$\frac{(T_2 - T_4)}{(T_3 - T_4)} = \frac{-2.059 \pm 0.149}{-0.165}$$

Using the values of gas flow rate previously obtained, the values of the temperature ratio obtained above, and the constant value of $c_{pg}/c_{ps} = 0.24/0.2 = 1.2$, values of R are calculated, using Equation (20), as presented in the following matrix:

Gas Flow Rate (lb/h)	Temperature Ratio $[(T_2 - T_4)/(T_3 - T_4)]$		
	-2.224	-2.059	-1.910
13,428	35,837	33,178	30,777
13,353	35,636	32,993	30,605
13,253	35,370	32,746	30,376

Since the true value of R is 33,000 lb/h, the percentage errors are as presented in Table B.1.

The maximum error in transfer-rate determination would be almost 9 percent, which is quite large considering the accuracy required in temperature measurement. Two additional error tables will be presented to indicate the magnitude of the error present under the following conditions:

- Case 1 - Maximum error in air-mass flow-rate determination and no error in temperature determinations.
- Case 2 - One-half of maximum error in air-mass flow-rate determination and maximum error in one temperature determination.

Under the conditions of Case 1, Equation (20) becomes:

$$R = 2.471 \text{ M.} \quad (23)$$

Table B.1 Errors in Bed-Material Transfer Rate Using Heat/Mass Transfer Analogy

(R) Bed-Material Transfer Rate (lb/h)	(ΔR) Absolute Error R - 33,000 (lb/h)	($\Delta R\%$) Percentage Error 100 $\Delta R/33,000$ (%)
35,837	+2837	+8.6
35,636	+2636	+8.0
35,370	+2370	+7.2
33,178	+178	+0.5
32,993	-7	-0.02
32,746	-254	-0.8
30,777	-2223	-6.7
30,605	-2395	-7.3
30,376	-2624	-8.0

Using the minimum and maximum values of M, the following table is generated:

Gas Flow Rate (lb/h)	Bed-Material Transfer Rate (lb/h)	Absolute Error R - 33,000 (lb/h)	Percentage Error 100 $\Delta R/33,000$ (percent)
13,253	32,746	-254	-0.8
13,428	33,178	+178	+0.5

Under the conditions of Case 2, the values of R in lb/h will be generated as presented in the following matrices:

Assuming a $\pm 0.1^\circ\text{F}$ error in T_2 :

Gas Flow Rate (lb/h)	Temperature Ratio $[(T_2 - T_4)/(T_3 - T_4)]$	
	-2.084	-2.033
13,403	33,158	32,698
13,303	33,268	32,454

Assuming a $\pm 0.1^\circ\text{F}$ error in T_3 :

<u>Gas Flow Rate (lb/h)</u>	<u>Temperature Ratio $[(T_2 - T_4)/(T_3 - T_4)]$</u>	
	<u>-2.007</u>	<u>-2.113</u>
13,403	32,280	33,985
13,303	32,039	33,731

Assuming a $\pm 0.1^\circ\text{F}$ error in T_4 :

<u>Gas Flow Rate (lb/h)</u>	<u>Temperature Ratio $[(T_2 - T_4)/(T_3 - T_4)]$</u>	
	<u>-2.139</u>	<u>-1.983</u>
13,403	34,403	31,894
13,303	34,146	31,656

The error in the values of R , under the conditions of Case 2, is presented in Table B.2. From a practical standpoint, Case 2 would appear to be the optimum condition realized in practice and, as shown in Table B.2, the error in bed transfer rate can be as high as 4.3 percent.

Weighbridge System

The basic analysis of the errors to be expected using the weighbridge system is statistical, because virtually all load-cell errors are random in nature and the errors will obey the normal probability laws. The basic measure of the dispersion of the random error distribution is the variance defined as:

$$\sigma^2 = \frac{1}{n} \sum_{i=1}^n (x_i)^2. \quad (24)$$

It can be shown that the individual, statistically independent, load-cell variances combine to form the composite load-cell error according to the following equation:

$$\sigma_T = (\sigma_1^2 + \sigma_2^2 + \dots + \sigma_n^2)^{1/2}. \quad (25)$$

Table B.2 Errors in Bed-Material Transfer Rate Using Heat/Mass Transfer Analogy (Case 2)

	(R) Bed-Material Transfer Rate (lb/h)	(ΔR) Absolute Error R - 33,000 (lb/h)	(ΔR%) Percentage Error 100 ΔR/33,000 (%)
<u>Error in T₂</u>	33,158	158	+0.5
	32,698	-302	-0.9
	33,268	268	+0.8
	32,454	-546	-1.7
<u>Error in T₃</u>	32,280	-720	-2.2
	33,985	985	3.0
	32,039	-961	-2.9
	33,731	731	+2.2
<u>Error in T₄</u>	34,403	1403	+4.3
	31,894	-1106	-3.4
	34,146	1146	+3.5
	31,656	-1344	-4.1

This equation also holds for statistical errors to any number of standard deviations ($e = n\sigma$). Equation (25) can, therefore, be rewritten as:

$$e_c = (e_1^2 + e_2^2 + \dots + e_n^2)^{1/2} \quad (26)$$

For a system employing multiple, identical load cells, the system absolute error obtained by application of Equation (25) is:

$$\beta_{TS} = (n\beta_I^2)^{1/2} \quad (27)$$

where:

- β_{TS} = Total system absolute error
- n = Number of load cells in system
- β_I = Individual cell composite absolute error.

If both sides are divided by the total system load-cell capacity, $X_T + nX$ (X is individual load-cell capacity), Equation (27) can be rewritten in terms of percentage errors:

$$\frac{\beta_{TS}}{X_T} = e_{TS} = \frac{(n\beta_I^2)^{1/2}}{nX} = \frac{e_c}{(n)^{1/2}} \quad (28)$$

where:

- e_{TS} = Total system percentage error
- e_c = Individual cell composite percentage error
- n = Number of load cells in system.

The load beams to be used in the weighbridge system are type LBPI, manufactured by BLH Electronics. Four cells, each having a rated capacity of 1000 lb, will be used in each weighbridge. The error percentages to be used, taken from BLH Bulletin 401-7 (1974), are as follows:

<u>Error</u>	<u>Percent of Rated Capacity</u>
Calibration accuracy	±0.25
Nonlinearity	±0.03
Hysteresis	±0.02
Repeatability	±0.01
Temperature effect on span	±0.0008 (load)/°F (reference temperature = 77°F)
Temperature effect on zero balance	±0.0015/°F (reference temperature = 77°F)

A ±25°F temperature variation (which allows operating temperatures between 52 and 102°F) would give temperature-effect errors of 0.02 percent (span) and 0.004 percent (zero balance).

Applying Equation (28) to these individual errors, for the load-beam composite error the following is obtained:

$$e_c = \left[(0.25)^2 + (0.03)^2 + (0.02)^2 + (0.01)^2 + (0.02)^2(0.004)^2 \right]^{1/2}$$

$$= 0.2536 \text{ percent of rated output.}$$

Applying Equation (28) to the load-beam composite errors yields:

$$e_{TS} = \frac{0.2536}{(4)^{\frac{1}{2}}} = 0.1268 \text{ percent of rated output}$$

This value of e_{TS} represents the worst-possible error. The error in the bed-material transfer rate, R , calculated using this error is presented below. The following assumptions are made:

Expanded bed density (ρ_{Bed})	= 62.4 lb/ft ³
Expanded bed height (h)	= 3 ft
Bed cross-sectional area (Ac.s.)	= 9.5 ft ²
True transfer rate (R)	= 33,000 lb/h
Actual transfer time measured (t)	= 30 s

Under these conditions, the initial weight in each bed (W_1) equals:

$$W_1 = (\rho_{\text{Bed}})(h)(\text{Ac.s.}) = (62.4)(3)(9.5) = 1778 \text{ lb.}$$

At a rate of transfer of 33,000 lb/h for 30 s, the true change in weight (ΔW) equals:

$$\Delta W = \frac{Rt}{3,600} = \frac{33,000(30)}{3,600} = 275 \text{ lb.}$$

The true weight in the second bed after transfer is $1778 + 275 = 2053$ lb. Applying the percentage-system error, e_{TS} , to a rated capacity of 4000 lb gives an error in the measurement of the bed weights (W_1 and W_2) of ± 5 lb. Using these values, an error table (Table B.3) is generated.

It is obvious from Table B.3 that the worst-possible error in the weighbridge system (3.64 percent) is less than the worst-probable error under Case 2 of the heat/mass transfer analogy system (4.3 percent). The actual error in the weighbridge system will be less than the maximum value given, since such errors as calibration accuracy can be eliminated. The worst error expected, if this error is eliminated, can be calculated (as was done previously), and the worst error in transfer rate would equal 0.6 percent, which rivals the very best error available with the heat/mass transfer analogy system.

Table B.3 Errors in Bed-Material Transfer Rate Using Weighbridge System

(W ₁) Weight in Bed 1 (lb)	(W ₂) Weight in Bed 2 (lb)	ΔW Weight Transferred (lb)	$\Delta(\Delta W)$ Absolute Error ($\Delta W - 275$) (lb)	$\Delta(\Delta W)\%$ Percentage Error ($100 \Delta(\Delta W)/275$)
1773	2053	280	5	1.82
1783	2053	270	-5	-1.82
1778	2048	270	-5	-1.82
1778	2058	280	5	1.82
1773	2058	285	10	3.64
1783	2048	265	-10	-3.64

COST COMPARISONHeat/Mass Transfer Analogy System

The major cost items in the heat/mass transfer analogy system are for the resistance thermometers required to measure temperatures to 0.1°F, duct heaters to heat the air to the regenerator bed approximately 20°F higher than the air to the gasifier bed, and a display device for recording the measured temperatures. Although one resistance thermometer would be adequate for a small vessel, a vessel almost 10 ft² in cross section will require many more. In fact, if the temperatures T₁, T₂, T₃, and T₄ (see Figure B.1) are to be measured to 0.1°F and if 1°F temperature variation across the cross-sectional area of the beds is assumed, 10 resistance thermometers at each measuring point are required. Based on catalog information and engineering judgment, the following price list for the major items of the heat/mass transfer system has been compiled:

<u>Quantity</u>	<u>Description</u>	<u>Unit Cost</u> (<u>\$</u>)	<u>Total Cost</u> (<u>\$</u>)
40	Resistance thermometers accurate to 0.1°F	150*	6,000
1	Digital, display and related circuitry	1,000	1,000
20	"Finstrips" - resistance heaters	32	640
1	Temperature controller	86	86
TOTAL			7,726

*Engineering estimate based on manufacturer's price for resistance thermometer with 0.5°F accuracy.

Weighbridge System

All that is required for the weighbridge system are eight load beams, a digital display, and two new perforated plates. From manufacturers' catalogs, the following price list has been compiled:

<u>Quantity</u>	<u>Description</u>	<u>Unit Cost</u> <u>(\$)</u>	<u>Total Cost</u> <u>(\$)</u>
8	LBPI - load beams	320	2,560
1	Digital display	984	984
2	Perforated plates	63	<u>126</u>
	TOTAL		3,670

CONCLUSIONS

It is evident from what has been presented in the preceding sections that the weighbridge system has many advantages over the heat/mass transfer analogy system. Not only is the weighbridge system considerably more accurate than the heat/mass transfer system, but it is also less expensive. The weighbridge system was therefore selected as the system to be used in the cold-model simulation of the CAFB demonstration plant bed-material transfer system.

APPENDIX C
PROCEDURE USED FOR DATA REDUCTION FOR THE CAFB
COLD-MODEL GASIFIER-REGENERATOR BED-MATERIAL TRANSFER TESTS

APPENDIX C

PROCEDURE USED FOR DATA REDUCTION FOR THE CAFB COLD-MODEL GASIFIER-REGENERATOR BED-MATERIAL TRANSFER TESTS

The purposes of this appendix are:

- To indicate what types of data were recorded during testing of the solids-transport systems
- To present in detail the calculational procedure used to reduce these data.

The types of data taken during testing of the solids-transport systems are presented in Table C.1, which is a reproduction of an actual data sheet. The data was subdivided into the following five categories or systems:

- Fluidizing-air bypass system
- Fluidized beds
- Transport-gas annubar measuring system
- Transport-gas spargers
- Bed-material transfer samples.

The calculational procedure used to reduce the data is presented in Table C.2. This table indicates the input data (a measured value from Table C.1 or an intermediate result) and the dimensional units associated with them. A conversion factor or calculational sequence that operates on the input datum is also presented. Finally, the calculated result is given together with its associated dimensional units.

Table C.1 CAFB Cold Model Data Sheet

0-59-6025 (R-114)

Bypass Orifice Diameter = 6.0"
Bypass Duct Diameter = 8.25"Date: _____
Taken By: _____

System	Measured Variable	Symbol	Units	Gasifier	Regenerator
Bypass	Orifice Differential Pressure	ΔP_o	in. of 2.95 Fl.	_____	_____
	Orifice Upstream Pressure	P_i	in. of 2.95 Fl.	_____	_____
	Orifice Downstream Temperature	t_o	$^{\circ}F$	_____	_____
	Fan Exit Pressure	$P_{\text{Fan Exit}}$	in. of 2.95 Fl.	_____	_____
	Fan Exit Temperature	$t_{\text{Fan Exit}}$	$^{\circ}F$	_____	_____
Beds	Fan Input Amps	Amps	Amps	_____	_____
	Plenum Temperature	t_{Plenum}	$^{\circ}F$	_____	_____
	Plenum Pressure	P_{Plenum}	in. of 2.0 Fl.	_____	_____
	Bed Differential Pressure (12 in.)	$\Delta P_{\text{Bed-12}}$	in. H ₂ O	_____	_____
	Bed Differential Pressure (24 in.)	$\Delta P_{\text{Bed-24}}$	in. H ₂ O	_____	_____
	Bed Differential Pressure (100 in.)	$\Delta P_{\text{Bed-100}}$	in. H ₂ O	_____	_____
	Pressure Above Bed	P_{Top}	in. H ₂ O	_____	_____
	Display	Display	---	_____	_____
	Bed Height	Bed Ht.	in.	_____	_____
	Operating Time	θ_{Op}	s	_____	_____
Annubar	Annubar Differential Pressure	$\Delta P_{\text{Annubar}}$	in. of 0.827 Fl.	_____	_____
	Annubar Downstream Temperature	t_{Annubar}	$^{\circ}F$	_____	_____
	Annubar Downstream Pressure	P_{Annubar}	lb/in ² g	_____	_____
Spargers	Pulse-Air Supply Temperature	t_{Tank}	$^{\circ}F$	_____	_____
	Pulse-Air Supply Pressure - Start	P_{Tank}	lb/in ² g	_____	_____
	- End	P_{Tank}	lb/in ² g	_____	_____
	Control Valve Signal Pressure	$P_{\text{Control Valve}}$	lb/in ² g	_____	_____
	Surge Tank Pressure	$P_{\text{Surge Tank}}$	lb/in ² g	_____	_____
	Sparger Pressure	P_{Sparger}	lb/in ² g	_____	_____
	Pulse to Regenerator - On Time	$\theta_{\text{Pulse 1}}$	Setting	_____	_____
	Pulse to Regenerator - Off Time	$\theta_{\text{Pulse 2}}$	Setting	_____	_____
	Pulse to Gasifier - On Time	$\theta_{\text{Pulse 3}}$	Setting	_____	_____
	Pulse to Gasifier - Off Time	$\theta_{\text{Pulse 4}}$	Setting	_____	_____
Samples	Gasifier to Regenerator 1	(Wt./30 s)	lb/30 s	_____	_____
	Gasifier to Regenerator 2	(Wt./30 s)	lb/30 s	_____	_____
	Gasifier to Regenerator 3	(Wt./30 s)	lb/30 s	_____	_____

Table C.2 Calculational Sequence for CAFB Solids Transport System Data Reduction

Step	Data* (Input)	Dimensional Units	Conversion Factor or Sequence	Results* (Output)	Dimensional Units
1	ΔP_o	in. of 2.95 Fl.	$\times 2.95$	ΔP_o	in. H ₂ O
2	P_1	in. of 2.95 Fl.	$\times (2.95/27.7) + 14.7$	P_1	lb/in ² a
3	t_o	°F	+ 460	T_1	°R
4	$P_{Fan Exit}$	in. of 2.95 Fl.	$\times (2.95/27.7) + 14.7$	$P_{Fan Exit}$	lb/in ² a
5	$t_{Fan Exit}$	°F	+ 460	$T_{Fan Exit}$	°R
6	T_1	°R	$\mu = \frac{(6.08642 \times 10^{-6})(T_1)^{1/2}}{(0.555(T_1) + 120)}$	μ	cp
7	d_o, D_1	in.	$\beta = (d_o/D_1)$	β	Dimensionless
8	$\beta, \Delta P_o, P_1$	See above	$Y = 1 - (0.41 + 0.35 \beta^4) \left(\frac{\Delta P_o}{(1.4)(27.7)(P_1)} \right)$	Y	Dimensionless
9†	$d_o, Y, \Delta P_o, T_1, P_1$	See above	$\dot{W}_{Bypass} = \left(\frac{Y}{4} \right) (144 d_o^2) (K) (V) \left(\frac{(2)(2.7)(g_c) \Delta P_o P_1}{T_1} \right)^{1/4}$	$\dot{W}_{Bypass}$	lb/s
10	$\dot{W}_{Bypass}$	lb/s	$\times 3600$	$\dot{W}_{Bypass}$	lb/h
11	Amps (G) Amps (R)	Amps	Amps (T) = Amps (G) + Amps (R)		
			$\dot{M}_{Total} (T) = 471.5317(\text{Amps } (T)) - 76091$		
			$\dot{M}_{Total} (G) = \dot{M}_{Total} (T) \times \frac{\text{Amps } (G)}{\text{Amps } (T)}$	$\dot{M}_{Total} (G)$	lb/h
			$\dot{M}_{Total} (R) = \dot{M}_{Total} (T) \times \frac{\text{Amps } (R)}{\text{Amps } (T)}$	$\dot{M}_{Total} (R)$	lb/h
12	$\dot{M}_{Total} (T)$	lb/h	$- \dot{M}_{Bypass} (T)$	$\dot{M}_{Fluidizing} (T)$	lb/h
	$\dot{M}_{Total} (G)$	lb/h	$- \dot{M}_{Bypass} (G)$	$\dot{M}_{Fluidizing} (G)$	lb/h
	$\dot{M}_{Total} (R)$	lb/h	$- \dot{M}_{Bypass} (R)$	$\dot{M}_{Fluidizing} (R)$	lb/h
13	t_{Plenum}	°F	+ 460	T_{Plenum}	°R
14	P_{Plenum}	in. of 2.0 Fl.	$\times (2/27.7) + 14.7$	P_{Plenum}	lb/in ² a
15	P_{Plenum}, T_{Plenum}	lb/in ² a, °R	$\rho_{Plenum} = (2.7)(P_{Plenum})/(T_{Plenum})$	ρ_{Plenum}	lb/ft ³

Table C.2 Calculational Sequence for CAFB Solids Transport System Data Reduction (Cont)

Step	Data* (Input)	Dimensional Units	Conversion Factor or Sequence	Results (Output)	Dimensional Units
16	$\dot{M}_{\text{Fluidizing}}$	lb/h	$V_{\text{Plenum}} = \frac{\dot{M}_{\text{Fluidizing}}}{(3600 \times \text{Area}_{\text{Plate}} \times \rho_{\text{Plenum}})}$	V_{Plenum}	ft/s
	Area _{Plate}	ft ²	Area _{Plate} = 9.68229 ft ²		
17	ρ_{Plenum}	lb/ft ³	$\times (1/27.7) + 14.7$	P_{Top}	lb/in ² a
18	$P_{\text{Top}}, T_{\text{Plenum}}$	in. H ₂ O		ρ_{Top}	lb/ft ³
		lb/in ² a, °R	$\rho_{\text{Top}} = (2.7)(P_{\text{Top}})/(T_{\text{Plenum}})$		
19	$\dot{M}_{\text{Fluidizing}}$	lb/h	$V_{\text{Top}} = \frac{\dot{M}_{\text{Fluidizing}}}{(3600 \times \text{Area}_{\text{Bed}} \times \rho_{\text{Top}})}$	V_{Top}	ft/s
	Area _{Bed}	ft ²			
	ρ_{Top}	lb/ft ³	Area _{Bed} = 9.68229 ft ²		
20	Display	Dimensionless	Use curve-fit correlations ^a	Bed Ht.	lb
21	Bed Ht.	in.	$\times 1$	Bed Ht.	in.
22	Bed Ht.	lb	$\rho_{\text{Bed}} = \frac{\text{Bed Ht.}}{(\text{Area}_{\text{Bed}})(\text{Bed Ht.}/12)}$	ρ_{Bed}	lb/ft ³
23	θ_{Op}	°	$\times 1$	θ_{Op}	°
24	t_{Tank}	min	$\times 60$	T_{Tank}	°R
		°F	+ 460		
25	P_{Tank} (start/end)	lb/in ² g	$\times 1$	P_{Tank} (start/end)	lb/in ² g
26	V_{Tank} (start)	lb/in ² g	$\Delta P_{\text{Tank}} = P_{\text{Tank}} (\text{start}) - P_{\text{Tank}} (\text{end})$	ΔP_{Tank}	lb/in ²
	V_{Tank} (end)	lb/in ² g	$\Delta \dot{M}_{\text{Total Air}} = \frac{(\dot{M}_{\text{Air}})(V_{\text{Tank}})(\Delta P_{\text{Tank}})}{(R)T_{\text{Tank}}}$	$\Delta \dot{M}_{\text{Total Air}}$	lb
27	ΔP_{Tank}	lb/in ²	$\dot{M}_{\text{Air}} = 29 \text{ lb/mol}$		
	T_{Tank}	°R	$V_{\text{Tank}} = 217.49 \text{ ft}^3$		
			$R = 10.73 \text{ (lb/in}^2\text{a}\cdot\text{ft}^3)/(^{\circ}\text{R}\cdot\text{mol)}$		
28	$\Delta \dot{M}_{\text{Total Air}}$	lb	$\text{Air Rate} = \frac{(60)(\Delta \dot{M}_{\text{Total}})}{\theta_{\text{Op}}}$	Air Rate	lb/min

Table C.2 Calculational Sequence for CAFB Solids Transport System Data Reduction (Cont)

Step	Data* (Input)	Dimensional Units	Conversion Factor or Sequence	Result* (Output)	Dimensional Units
29	$\Delta P_{\text{Annubar}}$	in. of 0.827 Fl.	$\times 0.827$	$\Delta P_{\text{Annubar}}$	in. H ₂ O
30	T_{Annubar}	$^{\circ}F$	+ 460	T_{Annubar}	$^{\circ}R$
31	P_{Annubar}	lb/in ² g	+ 14.7	P_{Annubar}	lb/in ² a
32	P_{Annubar}	lb/in ² a	$(2.7)(P_{\text{Annubar}}) \cdot$	P_{Annubar}	lb/in ² a
33	P_{Annubar}	$^{\circ}R$	$\frac{(2.7)(P_{\text{Annubar}})}{T_{\text{Annubar}}}$	P_{Annubar}	lb/ft ³
34	P_{Annubar}	lb/ft ³	$\dot{M}_{\text{Bleed Air}} = 11.125 \times (P_{\text{Bleed Air}} \times \Delta P_{\text{Annubar}})^{1/2}$	$\dot{M}_{\text{Bleed Air}}$	lb/min
35	$\dot{M}_{\text{Bleed Air}}$	in. H ₂ O	$\dot{M}_{\text{Pulse Air}} = \text{Air Rate} - \dot{M}_{\text{Bleed Air}}$	$\dot{M}_{\text{Pulse Air}}$	lb/min
36	$\dot{M}_{\text{Bleed Air}}$	lb/min	$\times 1$	$\dot{M}_{\text{Pulse Air}}$	lb/min
37	$\dot{M}_{\text{Bleed Air}}$	lb/min	Use calibration (Figures 4.4 - 4.7)	P_{Sparger}	lb/in ² g
38	$\dot{M}_{\text{Bleed Air}}$	lb/min	$\times \frac{(70 + 460)}{(2.7)(14.7)}$	Timer (on/off)	s
39	$\dot{M}_{\text{Bleed Air}}$	lb/min	Sample Average = $\frac{1}{N} \sum_{i=1}^N (\text{Sample})_i$	Volume (Air)	scf ³ /min
40	$\dot{M}_{\text{Bleed Air}}$	lb/min	Where N = No. of samples	Sample Average	lb/30 s
41	$\dot{M}_{\text{Bleed Air}}$	lb/min	$\times 120$	Material Rate	lb/h
42	$\dot{M}_{\text{Bleed Air}}$	lb/min	Transport Ratio = $\frac{\text{Material Rate}}{(60) \times \text{Volume (Air)}}$	Transport Ratio	(Air)(lb/scf ³)

*For definitions, see List of Symbols, p.

†K is a function of β , D_1 , d_0 and Re_D and is determined from the equations presented in ASME Fluid Meters, 6th ed. (Part II), p. 201. Since

Re_D is a function of W_{bypass} , the calculation of W_{bypass} is iterative.

§This is an approach velocity using the area of the plate only.

Range

590 < Display ≤ 1060
Display > 1060

A linear correlation coefficient (r^2) = 1 indicates a perfect linear relationship between the variables.

Equation

Bed Wt. = 1.95650 (Display) - 481.93510
Bed Wt. = 3.79979 (Display) - 2644.69362

Linear Correlation Coefficient

$r^2 = 0.99660$
 $r^2 = 0.98142$

APPENDIX D
CALCULATION SHEETS FOR THE PRIMARY GASIFIER-REGENERATOR
BED-MATERIAL TRANSFER SLOT--THIRD AND FOURTH GENERATIONS--
PRELIMINARY TESTS

Data Set: Case A

	<u>Gasifier</u>	<u>Regenerator</u>	
<u>Bypass</u>			<u>Notes</u>
ΔP_o (in. H_2O)			*Assume!
P_1 (lb/in ² a)			†Sample average
T_1 (°R)			‡Recycle on
$P_{Fan Exit}$ (lb/in ² a)			
$T_{Fan Exit}$ (°R)			
μ (cp)			
γ			
$\dot{M}_{Bypass}$ (lb/s)			
$\dot{M}_{Bypass}$ (lb/h)			
<u>Beds</u>			
Amps	165	150	
$\dot{M}_{Total}$ (lb/h)			
$\dot{M}_{Fluidizing}$ (lb/h)			
T_{Plenum} (°R)	560	562	
P_{Plenum} (lb/in ² a)			
ρ_{Plenum} (lb/ft ³)			
V_{Plenum} (ft/s)			
P_{Top} (lb/in ² a)			
ρ_{Top} (lb/ft ³)			
V_{Top} (ft/s)			
Display (start/end)	1156/1150	1148/1149	
Bed Wt. (start/end) (lb)	1977/1953	1945/1949	
Bed Ht. (start/end) (in.)	24/24	24/23.5	
ρ_{Bed} (start/end) (lb/ft ³)	102/101	100/103	
θ_{Op} (s)	900		
<u>Spargers</u>			
T_{Tank} (°R)	530*		
P_{Tank} (start/end) (lb/in ² g)	98/34		
ΔP_{Tank} (lb/in ²)	64		
$\dot{M}_{Total Air}$ (lb)	70.98		
Air Rate (lb/min)	4.73		
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)			
$P_{Sparger}$ (lb/in ² g)	6		
Timer (on/off) (s)			
Volume (Air) (sft ³ /min)	63.19		
Material Rate [†] (lb/h)	4104‡		
Transport Ratio (air) (lb/sft ³)	1.08		

Data Set: Case B

	<u>Gasifier</u>	<u>Regenerator</u>	
<u>Bypass</u>			<u>Notes</u>
ΔP_o (in. H_2O)			*Assumed
P_1 (lb/in ² a)			†Sample average
T_1 (°R)			Based on Δ bed weight
$P_{Fan Exit}$ (lb/in ² a)			(regenerator)
$T_{Fan Exit}$ (°R)			
μ (cp)			
γ			
$\dot{Q}_{Bypass}$ (lb/s)			
$\dot{M}_{Bypass}$ (lb/h)			
<u>Beds</u>			
Amps	150	150	
$\dot{M}_{Total}$ (lb/h)			
$\dot{M}_{Fluidizing}$ (lb/h)			
T_{Plenum} (°R)	110	110	
P_{Plenum} (lb/in ² a)			
ρ_{Plenum} (lb/ft ³)			
V_{Plenum} (ft/s)			
P_{Top} (lb/in ² a)			
ρ_{Top} (lb/ft ³)			
V_{Top} (ft/s)			
Display (start/end)	1160/1079	1145/1008	
Bed Wt. (start/end) (lb)	1993/1669	1945/1490	
Bed Ht. (start/end) (in.)	24/27	23.5/19.25	
ρ_{Bed} (start/end) (lb/ft ³)	103/77	103/96	
ϕ_{Op} (s)		600	
<u>Spargers</u>			
T_{Tank} (°R)	530*		
P_{Tank} (start/end) (lb/in ² g)	94.5/50.5		
ΔP_{Tank} (lb/in ²)	44		
$\Delta \dot{M}_{Total Air}$ (lb)	48.80		
Air Rate (lb/min)	4.88		
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)			
$P_{Sparger}$ (lb/in ² g)	6		
Timer (on/off) (s)			
Volume (Air) (sft ³ /min)	65.16		
Material Rate [†] (lb/h)	2730†		
Transport Ratio (air)(lb/sft ³)	0.7		

Data Set: Case C

	Gasifier	Regenerator	Notes
<u>Bypass</u>			
ΔP_o (in. H_2O)			
P_1 (lb/in ² a)			
T_1 (*R)			
$P_{Fan Exit}$ (lb/in ² a)			*Assumed
$T_{Fan Exit}$ (*R)			†Sample average
μ (cp)			§Recycle on
γ			
$\dot{Q}_{Bypass}$ (lb/s)			
$\dot{M}_{Bypass}$ (lb/h)			
<u>Beds</u>			
Amps	130	130	
$\dot{M}_{Total}$ (lb/h)			
$\dot{M}_{Fluidizing}$ (lb/h)			
T_{Plenum} (*R)	366	367	
P_{Plenum} (lb/in ² a)			
ρ_{Plenum} (lb/ft ³)			
V_{Plenum} (ft/s)			
P_{Top} (lb/in ² a)			
ρ_{Top} (lb/ft ³)			
V_{Top} (ft/s)			
Display (start/end)	1094/1084	1208/1110	
Bed Wt. (start/end) (lb)	1729/1689	2185/1793	
Bed Ht. (start/end) (in.)	21/21	25.5/27.25	
C_{Bed} (start/end) (lb/ft ³)	102/100	106/82	
Θ_{Op} (s)	600		
<u>Spargers</u>			
T_{Tank} (*R)	530*		
P_{Tank} (start/end) (lb/in ² g)	96/61		
ΔP_{Tank} (lb/in ²)	35		
$\Delta \dot{M}_{Total Air}$ (lb)	38.82		
Air Rate (lb/min)	3.88		
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (*R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)			
$P_{Sparger}$ (lb/in ² g)			
Timer (on/off)(s)			
Volume (Air) (sft ³ /min)	51.84		
Material Rate [†] (lb/h)	4104§	4104	
Transport Ratio (air)(lb/sft ³)	1.32		

Data Set: Case D

	Gasifier	Regenerator	Notes
<u>Bypass</u>			
ΔP_o (in. H_2O)			*Assumed
P_1 (lb/in ² a)			†Sample average
T_1 (°R)			‡Calculated from Δ bed weight (gasifier)
$P_{Fan Exit}$ (lb/in ² a)			
$T_{Fan Exit}$ (°R)			
μ (cp)			
γ			
$\dot{Q}_{Bypass}$ (lb/s)			
$\dot{M}_{Bypass}$ (lb/h)			
<u>Beds</u>			
Amps	150	165	
$\dot{M}_{Total}$ (lb/h)			
$\dot{M}_{Fluidizing}$ (lb/h)			
T_{Plenum} (°R)	560	560	
P_{Plenum} (lb/in ² a)			
ρ_{Plenum} (lb/ft ³)			
V_{Plenum} (ft/s)			
P_{Top} (lb/in ² a)			
ρ_{Top} (lb/ft ³)			
V_{Top} (ft/s)			
Display (start/end)	1052/1203	984/1050	
Bed Wt. (start/end) (lb)	1576/2165	1443/1572	
Bed Ht. (start/end) (in.)	21/25	26.25/19.5	
ρ_{Bed} (start/end) (lb/ft ³)	93/107	68/100	
Θ_{Op} (s)	600		
<u>Spargers</u>			
T_{Tank} (°R)	530*		
P_{Tank} (start/end) (lb/in ² g)	96/57		
ΔP_{Tank} (lb/in ²)	39		
$\dot{M}_{Total Air}$ (lb)	43.25		
Air Rate (lb/min)	4.33		
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)			
$P_{Sparger}$ (lb/in ² g)			
Timer (on/off) (s)			
Volume (Air) (ft ³ /min)	57.76		
Material Rate [†] (lb/h)	3534§		
Transport Ratio (air) (lb/ft ³)	1.02		

Data Set: Case E

	<u>Gasifier</u>	<u>Regenerator</u>	
<u>Bypass</u>			<u>Notes</u>
ΔP_o (in. H_2O)			*Assumed
P_1 (lb/in ² a)			†Sample average
T_1 (*R)			‡Calculated from Δ bed weight (regenerator)
$P_{Fan Exit}$ (lb/in ² a)			
$T_{Fan Exit}$ (*R)			
μ (cp)			
γ			
$\dot{Q}_{Bypass}$ (lb/s)			
$\dot{M}_{Bypass}$ (lb/h)			
<u>Beds</u>			
Amps	130	170	
$\dot{M}_{Total}$ (lb/h)			
$\dot{M}_{Fluidizing}$ (lb/h)			
T_{Plenum} (*R)	561	560	
P_{Plenum} (lb/in ² a)			
ρ_{Plenum} (lb/ft ³)			
V_{Plenum} (ft/s)			
P_{Top} (lb/in ² a)			
ρ_{Top} (lb/ft ³)			
V_{Top} (ft/s)			
Display (start/end)	1118/1183	1136/1095	
Bed Wt. (start/end) (lb)	1825/2085	1977/1733	
Bed Ht. (start/end) (in.)	21/24	24.5/21.25	
ρ_{Bed} (start/end) (lb/ft ³)	108/109	100/101	
ϕ_{Op} (s)	300		
<u>Spargers</u>			
T_{Tank} (*R)	530*		
P_{Tank} (start/end) (lb/in ² g)	91/71		
ΔP_{Tank} (lb/in ²)	20		
$\Delta \dot{V}_{Total Air}$ (lb)	22.18		
Air Rate (lb/min)	4.44		
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (*R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)			
$P_{Sparger}$ (lb/in ² g)			
Timer (on/off) (s)			
Volume (Air) (ft ³ /min)	59.24		
Material Rate [†] (lb/h)	2928‡		
Transport Ratio (air) (lb/ft ³)	0.82		

Data Set: Case F

	<u>Gasifier</u>	<u>Regenerator</u>	
<u>Bypass</u>			<u>Notes</u>
ΔP_o (in. H_2O)			*Assumed
P_1 (lb/in ² a)			†Sample average
T_1 (°R)			‡Calculated from Δ bed weight (regenerator)
$P_{Fan Exit}$ (lb/in ² a)			
$T_{Fan Exit}$ (°R)			
μ (cp)			
Y			
$\dot{Q}_{Bypass}$ (lb/s)			
$\dot{H}_{Bypass}$ (lb/h)			
<u>Beds</u>			
Amps	150	170	
$\dot{H}_{Total}$ (lb/h)			
$\dot{H}_{Fluidizing}$ (lb/h)			
T_{Plenum} (°R)	564	564	
P_{Plenum} (lb/in ² a)			
ρ_{Plenum} (lb/ft ³)			
V_{Plenum} (ft/s)			
P_{Top} (lb/in ² a)			
ρ_{Top} (lb/ft ³)			
V_{Top} (ft/s)			
Display (start/end)	1190/1196	1101/886	
Bed Wt. (start/end) (lb)	2113/2137	1757/1252	
Bed Ht. (start/end) (in.)	24/30	21.25/15	
ρ_{Bed} (start/end) (lb/ft ³)	109/88	102/103	
θ_{Op} (s)	240		
<u>Spargers</u>			
T_{Tank} (°R)	530*		
P_{Tank} (start/end) (lb/in ² g)	73/24		
ΔP_{Tank} (lb/in ²)	49		
$\Delta \dot{H}_{Total Air}$ (lb)	54.34		
Air Rate (lb/min)	13.59		
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{H}_{Bleed Air}$ (lb/min)			
$\dot{Q}_{Pulse Air}$ (lb/min)			
$P_{Sparger}$ (lb/in ² g)			
Timer (on/off) (s)			
Volume (Air) (sft ³ /min)	181.42		
Material Rate [†] (lb/h)	7575‡		
Transport Ratio (air) (lb/sft ³)	0.70		

Data Set: Case G

	<u>Gasifier</u>	<u>Regenerator</u>	
<u>Bypass</u>			
ΔP_0 (in. H_2O)			
P_1 (lb/in ² a)			
T_1 (°R)			
$P_{Fan Exit}$ (lb/in ² a)			
$T_{Fan Exit}$ (°R)			
u (cp)			
$\dot{Q}_{Bypass}$ (lb/s)			
$\dot{M}_{Bypass}$ (lb/h)			
<u>Beds</u>			
$\dot{M}_{Amps}$	130	163	
$\dot{M}_{Total}$ (lb/h)			
$\dot{M}_{Fluidizing}$ (lb/h)			
T_{Plenum} (°R)	370	370	
P_{Plenum} (lb/in ² a)			
ρ_{Plenum} (lb/ft ³)			
V_{Plenum} (ft/s)			
P_{Top} (lb/in ² a)			
ρ_{Top} (lb/ft ³)			
V_{Top} (ft/s)			
Display (start/end)	1104/1197	1186/1147	
Bed Wt. (start/end) (lb)	1769/2141	2097/1941	
Bed Ht. (start/end) (in.)	21/24	25/22	
ρ_{Bed} (start/end) (lb/ft ³)	104/111	104/109	
Θ_{Op} (s)	600		
<u>Spargers</u>			
T_{Tank} (°R)	330*		
P_{Tank} (start/end) (lb/in ² g)	96/47		
ΔP_{Tank} (lb/in ²)	49		
$\Delta \dot{M}_{Total Air}$ (lb)	34.34		
Air Rate (lb/min)	5.43		
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)			
$P_{Sparger}$ (lb/in ² g)			
Timer (on/off) (s)			
Volume (Air) (sft ³ /min)	72.57		
Material Rate [†] (lb/h)	3040†		
Transport Ratio (air) (lb/sft ³)	1.16		

Notes

*Assumed
[†]Sample average
 ‡Based on recycle rate +
 (3600)($\Delta \rho_{bed}$ (reg.))/ Θ_{Op}

Data Set: Case H

	<u>Gasifier</u>	<u>Regenerator</u>	
<u>Bypass</u>			
ΔP_o (in. H_2O)			
P_1 (lb/in ² a)			
T_1 (°R)			
$P_{Fan Exit}$ (lb/in ² a)			
$T_{Fan Exit}$ (°R)			
μ (cp)			
T			
$\dot{Q}_{Bypass}$ (lb/s)			
$\dot{M}_{Bypass}$ (lb/h)			
<u>Beds</u>			
Amps	150	170	
$\dot{Q}_{Total}$ (lb/h)			
$\dot{M}_{Fluidizing}$ (lb/h)			
T_{Plenum} (°R)	571	571	
P_{Plenum} (lb/in ² a)			
ρ_{Plenum} (lb/ft ³)			
V_{Plenum} (ft/s)			
P_{Top} (lb/in ² a)			
ρ_{Top} (lb/ft ³)			
V_{Top} (ft/s)			
Display (start/end)	1197/1229	1147/958	
Bed Wt. (start/end) (lb)	2141/2269	1941/1392	
Bed Ht. (start/end) (in.)	24/27	22/17	
ρ_{Bed} (start/end) (lb/ft ³)	111/104	109/102	
θ_{Op} (s)	360		
<u>Spargers</u>			
T_{Tank} (°R)	530*		
P_{Tank} (start/end) (lb/in ² g)	88/32		
ΔP_{Tank} (lb/in ²)	56		
$\dot{M}_{Total Air}$ (lb)	62.11		
Air Rate (lb/min)	10.35		
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)			
$P_{Sparger}$ (lb/in ² g)			
Timer (on/off)(s)			
Volume (Air) (sft ³ /min)	138.23		
Material Rate ⁺ (lb/h)	95941		
Transport Ratio (air)(lb/sft ³)	1.16		

Notes

*Assumed
 †Sample average
 ‡Based on recycle rate +
 (3600)($\Delta \mu_{bed (reg.)}$)/ θ_{Op}

Data Set: Case I

	<u>Casifier</u>	<u>Regenerator</u>
<u>Bypass</u>		
ΔP_o (in. H_2O)		
P_1 (lb/in ² a)		
T_1 (°R)		
$P_{Fan Exit}$ (lb/in ² a)		
$T_{Fan Exit}$ (°R)		
μ (cp)		
γ		
$\dot{Q}_{Bypass}$ (lb/s)		
$\dot{M}_{Bypass}$ (lb/h)		
<u>Beds</u>		
Amps	132	162
$\dot{M}_{Total}$ (lb/h)		
$\dot{M}_{Fluidizing}$ (lb/h)		
T_{Plenum} (°R)	580	580
P_{Plenum} (lb/in ² a)		
ρ_{Plenum} (lb/ft ³)		
V_{Plenum} (ft/s)		
P_{Top} (lb/in ² a)		
ρ_{Top} (lb/ft ³)		
V_{Top} (ft/s)		
Display (start/end)	990/1179	1243/926
Bed Wt. (start/end) (lb)	1455/2069	2325/1330
Bed Ht. (start/end) (in.)	18/27	26/15
ρ_{Bed} (start/end) (lb/ft ³)	100/95	111/110
$\dot{Q}_{Op}$ (s)	300	
<u>Spargers</u>		
T_{Tank} (°R)	530*	
P_{Tank} (start/end) (lb/in ² g)	94/54	
ΔP_{Tank} (lb/in ²)	40	
$\dot{M}_{Total Air}$ (lb)	44.36	
Air Rate (lb/min)	8.87	
$\Delta P_{Annubar}$ (in. H_2O)		
$T_{Annubar}$ (°R)		
$P_{Annubar}$ (lb/in ² a)		
$\rho_{Bleed Air}$ (lb/ft ³)		
$\dot{M}_{Bleed Air}$ (lb/min)		
$\dot{M}_{Pulse Air}$ (lb/min)		
$P_{Sparger}$ (lb/in ² g)		
Timer (on/off)(s)		
Volume (Air) (sft ³ /min)	118.48	
Material Rate [†] (lb/h)	16,044	
Transport Ratio (air) (lb/sft ³)	2.26	

Notes

*Assumed
[†]Sample average
 ‡Based on recycle rate +
 (3600)($\Delta \rho_{bed (reg.)}$)/ θ_{Op}

Data Set: Case J

	Gasifier	Regenerator
<u>Bypass</u>		
ΔP_o (in. H_2O)		
P_1 (lb/in ² a)		
T_1 (°R)		
$P_{Fan Exit}$ (lb/in ² a)		
$T_{Fan Exit}$ (°R)		
u (cp)		
γ		
$\dot{Q}_{Bypass}$ (lb/s)		
$\dot{M}_{Bypass}$ (lb/h)		
<u>Beds</u>		
Amps	150	162
$\dot{M}_{Total}$ (lb/h)		
$\dot{M}_{Fluidizing}$ (lb/h)		
T_{Plenum} (°R)	583	583
P_{Plenum} (lb/in ² a)		
C_{Plenum} (lb/ft ³)		
V_{Plenum} (ft/s)		
F_{Top} (lb/in ² a)		
C_{Top} (lb/ft ³)		
V_{Top} (ft/s)		
Display (start/end)	1078/1151	1186/1118
Bed Wt. (start/end) (lb)	1665/1957	2097/1825
Bed Ht. (start/end) (in.)	19/22	25.25/21.25
C_{Bed} (start/end) (lb/ft ³)	109/110	103/106
G_{Op} (s)	900	
<u>Spargers</u>		
T_{Tank} (°R)	530*	
P_{Tank} (start/end) (lb/in ² g)		
ΔP_{Tank} (lb/in ²)		
$\Delta \dot{M}_{Total Air}$ (lb)		
Air Rate (lb/min)	8.875	
$\Delta P_{Annubar}$ (in. H_2O)		
$T_{Annubar}$ (°R)		
$P_{Annubar}$ (lb/in ² a)		
$C_{Bleed Air}$ (lb/ft ³)		
$\dot{M}_{Bleed Air}$ (lb/min)		
$\dot{M}_{Pulse Air}$ (lb/min)		
$P_{Sparger}$ (lb/in ² g)	5	
Timer (on/off) (s)		
Volume (Air) (sft ³ /min)	118.48	
Material Rate [†] (lb/h)	5192†	
Transport Ratio (air) (lb/sft ³)	0.73	

Notes

*Assumed
 ‡Air rate assumed equal to that of Test I
 †Sample average
 ‡Based on recycle rate + (3600)($\Delta W_{bed (reg.)}$)/ G_{Op}

Data Set: Case K

	Gasifier	Regenerator	Notes
<u>Bypass</u>			
ΔP_0 (in. H_2O)			*Assumed
P_1 (lb/in ² a)			†Sample average
T_1 (*R)			‡Based on recycle rate +
$P_{Fan Exit}$ (lb/in ² a)			(3600)($\Delta H_{bed (reg.)}$)/ θ_{Op}
$T_{Fan Exit}$ (*R)			
μ (cp)			
γ			
$\dot{Q}_{Bypass}$ (lb/s)			
$\dot{H}_{Bypass}$ (lb/h)			
<u>Beds</u>			
Amps	150	163	
$\dot{H}_{Total}$ (lb/h)			
$\dot{H}_{Fluidizing}$ (lb/h)			
T_{Plenum} (*R)	565	565	
P_{Plenum} (lb/in ² a)			
ρ_{Plenum} (lb/ft ³)			
V_{Plenum} (ft/s)			
P_{Top} (lb/in ² a)			
ρ_{Top} (lb/ft ³)			
V_{Top} (ft/s)			
Display (start/end)	1174/1156	1120/908	
Bed Wt. (start/end) (lb)	2049/1977	1833/1295	
Bed Ht. (start/end) (in.)	22/26	21/15	
ρ_{Bed} (start/end) (lb/ft ³)	115/94	108/107	
θ_{Op} (s)	300		
<u>Spargers</u>			
T_{Tank} (*R)	530*		
P_{Tank} (start/end) (lb/in ² g)	85/47		
ΔP_{Tank} (lb/in ²)	38		
$\Delta \dot{H}_{Total Air}$ (lb)	42.14		
Air Rate (lb/min)	8.43		
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (*R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{H}_{Bleed Air}$ (lb/min)			
$\dot{H}_{Pulse Air}$ (lb/min)			
$P_{Sparger}$ (lb/in ² g)			
Timer (on/off) (s)			
Volume (Air) (scf ³ /min)	112.36		
Material Rate (lb/h)	10,560†		
Transport Ratio (air)(lb/scf ³)	1.36		

Data Set: Case L

	<u>Gasifier</u>	<u>Regenerator</u>	<u>Notes</u>
<u>Bypass</u>			
ΔP_o (in. H_2O)			
P_1 (lb/in ² a)			
T_1 (°R)			
$P_{Fan Exit}$ (lb/in ² a)			
$T_{Fan Exit}$ (°R)			
μ (cp)			
η			
$\dot{Q}_{Bypass}$ (lb/s)			
$\dot{M}_{Bypass}$ (lb/h)			
<u>Beds</u>			
Amps	150	162	
$\dot{M}_{Total}$ (lb/h)			
$\dot{M}_{Fluidizing}$ (lb/h)			
T_{Plenum} (°R)	578	574	
P_{Plenum} (lb/in ² a)			
ρ_{Plenum} (lb/ft ³)			
V_{Plenum} (ft/s)			
P_{Top} (lb/in ² a)			
ρ_{Top} (lb/ft ³)			
V_{Top} (ft/s)			
Display (start/end)	1136/1251	1149/925	
Bed Wt. (start/end) (lb)	1897/2357	1949/1328	
Bed Ht. (start/end) (in.)	21/28	22.5/16	
ρ_{Bed} (start/end) (lb/ft ³)	112/104	107/103	
θ_{Op} (s)	900		
<u>Spargers</u>			
T_{Tank} (°R)	530*		
P_{Tank} (start/end) (lb/in ² g)			
ΔP_{Tank} (lb/in ²)			
$\dot{M}_{Total Air}$ (lb)			
Air Rate (lb/min)	8.435		
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)			
$P_{Sparger}$ (lb/in ² g)			
Timer (on/off) (s)			
Volume (Air) (sft ³ /min)	112.56		
Material Rate ⁺ (lb/h)	65887		
Transport Ratio (air) (lb/sft ³)	0.98		

Data Set: Case M

	<u>Gasifier</u>	<u>Regenerator</u>	
<u>Bypass</u>			<u>Notes</u>
ΔP_o (in. H_2O)			*Assumed
P_1 (lb/in ² a)			†Sample average
T_1 (°R)			Based on recycle rate +
$P_{Fan Exit}$ (lb/in ² a)			(3600)($\Delta V_{bed (reg.)}$)/ θ_{Op}
$T_{Fan Exit}$ (°R)			
μ (cp)			
γ			
$\dot{M}_{Bypass}$ (lb/s)			
$\dot{M}_{Bypass}$ (lb/h)			
<u>Beds</u>			
Amps	150	155	
$\dot{M}_{Total}$ (lb/h)			
$\dot{M}_{Fluidizing}$ (lb/h)			
T_{Plenum} (°R)	578	578	
P_{Plenum} (lb/in ² a)			
ρ_{Plenum} (lb/ft ³)			
V_{Plenum} (ft/s)			
P_{Top} (lb/in ² a)			
ρ_{Top} (lb/ft ³)			
V_{Top} (ft/s)			
Display (start/end)	1080/1173	1193/923	
Bed Wt. (start/end) (lb)	1673/2045	2125/1324	
Bed Ht. (start/end) (in.)	20/27	23.5/16	
ρ_{Bed} (start/end) (lb/ft ³)	104/94	112/103	
θ_{Op} (s)	340		
<u>Spargers</u>			
T_{Tank} (°R)	530*		
P_{Tank} (start/end) (lb/in ² g)	91/30		
ΔP_{Tank} (lb/in ²)	61		
$\dot{M}_{Total Air}$ (lb)	67.65		
Air Rate (lb/min)	7.52		
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)			
$P_{Sparger}$ (lb/in ² g)			
Timer (on/off) (s)			
Volume (Air) (scf ³ /min)	100.38		
Material Rate [†] (lb/h)	94448		
Transport Ratio (air) (lb/scf ³)	1.57		

Data Set: Case N

	<u>Casifier</u>	<u>Regenerator</u>	
<u>Bypass</u>			<u>Notes</u>
ΔP_o (in. H_2O)			*Assumed
P_1 (lb/in ² a)			†Sample average
T_1 (°R)			‡Based on recycle rate +
$P_{Fan Exit}$ (lb/in ² a)			(3600)($\Delta V_{bed (reg.)}$) ^{1/6} Q_p
$T_{Fan Exit}$ (°R)			
μ (cp)			
T			
$\dot{Q}_{Bypass}$ (lb/s)			
$\dot{H}_{Bypass}$ (lb/h)			
<u>Beds</u>			
Amps	132	160	
$\dot{H}_{Total}$ (lb/h)			
$\dot{H}_{Fluidizing}$ (lb/h)			
T_{Plenum} (°R)	545	545	
P_{Plenum} (lb/in ² a)			
ρ_{Plenum} (lb/ft ³)			
V_{Plenum} (ft/s)			
P_{Top} (lb/in ² a)			
ρ_{Top} (lb/ft ³)			
V_{Top} (ft/s)			
Display (start/end)	1194/1253	1086/988	
Bed Wt. (start/end) (lb)	2129/2365	1697/1451	
Bed Ht. (start/end) (in.)	25/28	22/18	
ρ_{Bed} (start/end) (lb/ft ³)	106/105	96/100	
θ_{Op} (s)	420		
<u>Spargers</u>			
T_{Tank} (°R)	530*		
P_{Tank} (start/end) (lb/in ² g)	98/50		
ΔP_{Tank} (lb/in ²)	48		
$\Delta \dot{H}_{Total Air}$ (lb)	53.24		
Air Rate (lb/min)	7.61		
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{H}_{Bleed Air}$ (lb/min)			
$\dot{Q}_{Pulse Air}$ (lb/min)			
$P_{Sparger}$ (lb/in ² g)			
Timer (on/off) (s)			
Volume (Air) (scf ³ /min)	101.55		
Material Rate [†] (lb/h)	87895		
Transport Ratio (air) (lb/scf ³)	1.44		

Data Set: Case 0

	<u>Gasifier</u>	<u>Regenerator</u>
<u>Bypass</u>		
ΔP_0 (in. H_2O)		
P_1 (lb/in ² a)		
T_1 (°R)		
$P_{Fan Exit}$ (lb/in ² a)		
$T_{Fan Exit}$ (°R)		
μ (cp)		
γ		
$\dot{Q}_{Bypass}$ (lb/s)		
$\dot{M}_{Bypass}$ (lb/h)		
<u>Beds</u>		
$\dot{M}_{Total}$ (lb/h)	155	160
$\dot{M}_{Fluidizing}$ (lb/h)		
T_{Plenum} (°R)	587	587
P_{Plenum} (lb/in ² a)		
ρ_{Plenum} (lb/ft ³)		
V_{Plenum} (ft/s)		
P_{Top} (lb/in ² a)		
ρ_{Top} (lb/ft ³)		
V_{Top} (ft/s)		
Display (start/end)	1212/1217	1108/785
Bed Wt. (start/end) (lb)	2201/2221	1785/1054
Bed Ht. (start/end) (in.)	25/32	21/12.75
ρ_{Bed} (start/end) (lb/ft ³)	109/86	105/102
θ_{Op} (s)	318.8	
<u>Spargers</u>		
T_{Tank} (°R)	530*	
P_{Tank} (start/end) (lb/in ² g)		
ΔP_{Tank} (lb/in ²)		
$\Delta \dot{M}_{Total Air}$ (lb)		
Air Rate (lb/min)	7.615	
$\Delta P_{Annubar}$ (in. H_2O)		
$T_{Annubar}$ (°R)		
$P_{Annubar}$ (lb/in ² a)		
$\rho_{Bleed Air}$ (lb/ft ³)		
$\dot{M}_{Bleed Air}$ (lb/min)		
$\dot{M}_{Pulse Air}$ (lb/min)		
$P_{Sparger}$ (lb/in ² g)		
Timer (on/off)(s)		
Volume (Air) (sft ³ /min)	101.55	
Material Rate [†] (lb/h)	14,935*	
Transport Ratio (air)(lb/sft ³)	2.45	

Notes

*Assumed
 ‡Recycle and air rate
 assumed equal to values
 from Case N
 †Sample average
 ‡Based on recycle rate +
 (3600)($\Delta \dot{M}_{bed (reg.)}$)/ θ_{Op}

Data Set: Case P

	<u>Gasifier</u>	<u>Regenerator</u>
<u>Bypass</u>		
ΔP_o (in. H_2O)		
P_1 (lb/in ² a)		
T_1 (°R)		
$P_{Fan Exit}$ (lb/in ² a)		
$T_{Fan Exit}$ (°R)		
μ (cp)		
γ		
$\dot{Q}_{Bypass}$ (lb/s)		
$\dot{H}_{Bypass}$ (lb/h)		
<u>Beds</u>		
Amps		
$\dot{H}_{Total}$ (lb/h)		
$\dot{H}_{Fluidizing}$ (lb/h)		
T_{Plenum} (°R)		
P_{Plenum} (lb/in ² a)		
ρ_{Plenum} (lb/ft ³)		
V_{Plenum} (ft/s)		
P_{Top} (lb/in ² a)		
ρ_{Top} (lb/ft ³)		
V_{Top} (ft/s)		
Display (start/end)	1218/934	1234/1063
Bed Wt. (start/end) (lb)	2225/1343	2289/1605
Bed Ht. (start/end) (ft.)	23/29	27/19
ρ_{Bed} (start/end) (lb/ft ³)	120/58	103/103
θ_{Op} (s)	390	
<u>Spargers</u>		
T_{Tank} (°R)	530*	
P_{Tank} (start/end) (lb/in ² g)	96.5/60.5	
ΔP_{Tank} (lb/in ²)	36	
$\Delta \dot{H}_{Total Air}$ (lb)	39.93	
Air Rate (lb/min)	6.14	
$\Delta P_{Annubar}$ (in. H_2O)		
$T_{Annubar}$ (°R)		
$P_{Annubar}$ (lb/in ² a)		
$\rho_{Bleed Air}$ (lb/ft ³)		
$\dot{H}_{Bleed Air}$ (lb/min)		
$\dot{H}_{Pulse Air}$ (lb/min)		
$P_{Sparger}$ (lb/in ² g)		
Timer (on/off) (s)		
Volume (Air) (sft ³ /min)	82.02	
Material Rate [†] (lb/h)	20,114	
Transport Ratio (air)(lb/sft ³)	4.09	

Notes

*Assumed
[†]Sample average
 Based on recycle rate +
 (3600)($\Delta H_{bed (reg.)}$)/ θ_{Op}

Data Set: Case Q

	<u>Casifier</u>	<u>Regenerator</u>	<u>Notes</u>
<u>Bypass</u>			
ΔP_o (in. H_2O)			*Assumed
P_1 (lb/in ² a)			†Sample average
T_1 (*R)			‡Based on recycle rate +
$P_{Fan Exit}$ (lb/in ² a)			(3600)($\Delta \dot{M}_{bed (reg.)}$)/ θ_{Op}
$T_{Fan Exit}$ (*R)			Recycle rate was assumed
μ (cp)			equal to that of Case P
$\dot{Q}_{Bypass}$ (lb/s)			
$\dot{M}_{Bypass}$ (lb/h)			
<u>Beds</u>			
$\dot{M}_{Total}$ (lb/h)	150	160	
$\dot{M}_{Fluidizing}$ (lb/h)			
T_{Plenum} (*R)	577		
P_{Plenum} (lb/in ² a)			
ρ_{Plenum} (lb/ft ³)			
V_{Plenum} (ft/s)			
P_{Top} (lb/in ² a)			
ρ_{Top} (lb/ft ³)			
V_{Top} (ft/s)			
Display (start/end)	1237/1331	1243/1120	
Bed Wt. (start/end) (lb)	2301/2676	2325/1833	
Bed Ht. (start/end) (in.)	26/30	25/20	
ρ_{Bed} (start/end) (lb/ft ³)	110/111	115/114	
θ_{Op} (s)	319.1		
<u>Spargers</u>			
T_{Tank} (*R)	330*		
P_{Tank} (start/end) (lb/in ² g)	100/29		
ΔP_{Tank} (lb/in ²)	71		
$\Delta \dot{M}_{Total Air}$ (lb)	78.74		
Air Rate (lb/min)	9.10		
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (*R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)			
$P_{Sparger}$ (lb/in ² g)	=6		
Timer (on/off) (s)			
Volume (Air) (sft ³ /min)	121.54		
Material Rate [†] (lb/h)	17,2125		
Transport Ratio (air) (lb/sft ³)	2.36		

Data Set: Case R

	Gasifier	Regenerator	Notes
<u>Bypass</u>			
ΔP_0 (in. H_2O)			*Assumed
P_1 (lb/in ² a)			†Sample average
T_1 (°R)			‡Based on recycle rate +
$P_{Fan Exit}$ (lb/in ² a)			(3600)($\Delta H_{bed (reg.)}$)/ θ_{Op}
$T_{Fan Exit}$ (°R)			Recycle rate assumed equal
μ (cp)			to that of Case P
γ			
$\dot{Q}_{Bypass}$ (lb/s)			
$\dot{M}_{Bypass}$ (lb/h)			
<u>Beds</u>	130	160	
$\dot{M}_{Total}$ (lb/h)			
$\dot{M}_{Fluidising}$ (lb/h)			
T_{Plenum} (°R)	581		
P_{Plenum} (lb/in ² a)			
ρ_{Plenum} (lb/ft ³)			
V_{Plenum} (ft/s)			
P_{Top} (lb/in ² a)			
ρ_{Top} (lb/ft ³)			
V_{Top} (ft/s)			
Display (start/end)	1276/1278	1245/1152	
Bed Wt. (start/end) (lb)	2456/2464	2333/1961	
Bed Ht. (start/end) (in.)	26/26	25/23	
ρ_{Bed} (start/end) (lb/ft ³)	117/117	116/106	
θ_{Op} (s)	548.5		
<u>SPARGER</u>			
T_{Tank} (°R)	530*		
P_{Tank} (start/end) (lb/in ² g)	100/25		
ΔP_{Tank} (lb/in ²)	75		
$\dot{M}_{Total Air}$ (lb)	83.18		
Air Rate (lb/min)	9.10		
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)			
$P_{Sparger}$ (lb/in ² g)	6.5		
Timer (on/off) (s)			
Volume (Air) (ft ³ /min)	121.50		
Material Rate [†] (lb/h)	16,242‡		
Transport Ratio (air) (lb/ft ³)	2.23		

Data Set: Case S

	<u>Gasifier</u>	<u>Regenerator</u>
<u>Bypass</u>		
ΔP_0 (in. H_2O)		
P_1 (lb/in ² a)		
T_1 (*R)		
$P_{Fan Exit}$ (lb/in ² a)		
$T_{Fan Exit}$ (*R)		
μ (cp)		
Y		
$\dot{Q}_{Bypass}$ (lb/s)		
$\dot{M}_{Bypass}$ (lb/h)		
<u>Beds</u>		
Amps	150	160
$\dot{M}_{Total}$ (lb/h)		
$\dot{M}_{Fluidizing}$ (lb/h)		
T_{Plenum} (*R)	584	
P_{Plenum} (lb/in ² a)		
ρ_{Plenum} (lb/ft ³)		
V_{Plenum} (ft/s)		
P_{Top} (lb/in ² a)		
ρ_{Top} (lb/ft ³)		
V_{Top} (ft/s)		
Display (start/end)	1300/1246	1161/1130
Bed Wt. (start/end) (lb)	2552/2337	1997/1873
Bed Ht. (start/end) (in.)	26/28	23/20.5
ρ_{Bed} (start/end) (lb/ft ³)	122/103	108/113
ϕ_{Op} (s)	420	
<u>Spargers</u>		
T_{Tank} (*R)	530*	
P_{Tank} (start/end) (lb/in ² g)	100/26.5	
ΔP_{Tank} (lb/in ²)	73.5	
$\Delta \dot{M}_{Total Air}$ (lb)	81.52	
Air Rate (lb/min)	11.65	
$\Delta P_{Annubar}$ (in. H_2O)		
$T_{Annubar}$ (*R)		
$P_{Annubar}$ (lb/in ² a)		
$\rho_{Bleed Air}$ (lb/ft ³)		
$\dot{M}_{Bleed Air}$ (lb/min)		
$\dot{M}_{Pulse Air}$ (lb/min)		
$P_{Sparger}$ (lb/in ² g)	6.5	
Timer (on/off) (s)		
Volume (Air) (scf ³ /min)	153.51	
Material Rate (lb/h)	14,863	
Transport Ratio (air) (lb/scf ³)	1.59	

Notes

*Assumed
†Sample average
‡Based on recycle rate +
(3600)($\Delta W_{bed (reg.)}$)/ ϕ_{Op}
Recycle rate assumed equal
to that of Case F

Data Set: Case T

		Casifier	Regenerator	Notes
<u>Bypass</u>	ΔP_0 (in. H_2O)			*Assumed
	P_1 (lb/in ² a)			+Sample average
	T_1 (*R)			Based on recycle rate +
	$P_{Fan Exit}$ (lb/in ² a)			(3600)($\Delta H_{bed (reg.)}$)/ θ_{Op}
	$T_{Fan Exit}$ (*R)			Recycle rate assumed equal
	μ (cp)			to that of Case P
	Y			
	$\dot{M}_{Bypass}$ (lb/s)			
	$\dot{M}_{Bypass}$ (lb/h)			
<u>Beds</u>	Amps	150	160	
	$\dot{M}_{Total}$ (lb/h)			
	$\dot{M}_{Fluidizing}$ (lb/h)			
	T_{Plenum} (*R)	584		
	P_{Plenum} (lb/in ² a)			
	ρ_{Plenum} (lb/ft ³)			
	V_{Plenum} (ft/s)			
	P_{Top} (lb/in ² a)			
	ρ_{Top} (lb/ft ³)			
	V_{Top} (ft/s)			
	Display (start/end)	1200/1275	1282/1117	
	Bed Wt. (start/end) (lb)	2153/2452	2480/1821	
	Bed Ht. (start/end) (in.)	21/29	27/21	
	ρ_{Bed} (start/end) (lb/ft ³)	127/105	114/107	
	θ_{Op} (s)	381		
<u>Spargers</u>	T_{Tank} (*R)	530*		
	P_{Tank} (start/end) (lb/in ² g)	100/25		
	ΔP_{Tank} (lb/in ²)	75		
	$\Delta H_{Total Air}$ (lb)	83.18		
	Air Rate (lb/min)	13.10		
	$\Delta P_{Annubar}$ (in. H_2O)			
	$T_{Annubar}$ (*R)			
	$P_{Annubar}$ (lb/in ² a)			
	$\rho_{Bleed Air}$ (lb/ft ³)			
	$\dot{M}_{Bleed Air}$ (lb/min)			
	$\dot{M}_{Pulse Air}$ (lb/min)			
	$P_{Sparger}$ (lb/in ² g)	6.5		
	Timer (on/off) (s)			
	Volume (Air) (sft ³ /min)	174.92		
	Material Rate ⁺ (lb/h)	20,027 ⁺		
	Transport Ratio (air) (lb/sft ³)	1.91		

Data Set: Case U

	Gasifier	Regenerator	Notes
<u>Bypass</u>			
ΔP_0 (in. H_2O)			*Assumed
P_1 (lb/in ² a)			†Sample average
T_1 (°R)			‡Based on recycle rate +
$P_{Fan Exit}$ (lb/in ² a)			(3600)($\Delta H_{bed (reg.)}$)/ θ_{Op}
$T_{Fan Exit}$ (°R)			
μ (cp)			
γ			
$\dot{M}_{Bypass}$ (lb/s)			
$\dot{M}_{Bypass}$ (lb/h)			
<u>Beds</u>	130		
$\dot{M}_{Total}$ (lb/h)			
$\dot{M}_{Fluidizing}$ (lb/h)			
T_{Plenum} (°R)			
P_{Plenum} (lb/in ² a)			
ρ_{Plenum} (lb/ft ³)			
V_{Plenum} (ft/s)			
P_{Top} (lb/in ² a)			
ρ_{Top} (lb/ft ³)			
V_{Top} (ft/s)			
Display (start/end)	1184/1217	1199/932	
Bed Wt. (start/end) (lb)	2089/2221	2149/1381	
Bed Ht. (start/end) (in.)	24/32	24/16	
ρ_{Bed} (start/end) (lb/ft ³)	108/86	111/107	
θ_{Op} (s)	392.1		
<u>Spargers</u>			
T_{Tank} (°R)	330*		
P_{Tank} (start/end) (lb/in ² g)	99/20		
ΔP_{Tank} (lb/in ²)	79		
$\Delta \dot{M}_{Total Air}$ (lb)	87.62		
Air Rate (lb/min)	8.84		
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)			
$P_{Sparger}$ (lb/in ² g)	7		
Timer (on/off) (s)	1.25/1.15		
Volume (Air) (sft ³ /min)	119.56		
Material Rate [†] (lb/h)	26.6295		
Transport Ratio (air) (lb/sft ³)	3.74		

Data Set: Case V

	Gasifier	Regenerator
<u>Bypass</u>		
ΔP_0 (in. H_2O)		
P_1 (lb/in ² a)		
T_1 (°R)		
$P_{Fan Exit}$ (lb/in ² a)		
$T_{Fan Exit}$ (°R)		
μ (cp)		
Y		
$\dot{Q}_{Bypass}$ (lb/s)		
$\dot{H}_{Bypass}$ (lb/h)		
<u>Beds</u>		
Amps		
$\dot{H}_{Total}$ (lb/h)		
$\dot{H}_{Fluidizing}$ (lb/h)		
T_{Plenum} (°R)		
P_{Plenum} (lb/in ² a)		
ρ_{Plenum} (lb/ft ³)		
V_{Plenum} (ft/s)		
P_{Top} (lb/in ² a)		
ρ_{Top} (lb/ft ³)		
V_{Top} (ft/s)		
Display (start/end)	1191/1250	1218/1070
Bed Wt. (start/end) (lb)	2117/2353	2225/1633
Bed Ht. (start/end) (in.)	24/28	24/20
ρ_{Bed} (start/end) (lb/ft ³)	109/104	115/101
Θ_{Op} (s)	507	
<u>Spargers</u>		
T_{Tank} (°R)	530*	
P_{Tank} (start/end) (lb/in ² g)	98.5/25	
ΔP_{Tank} (lb/in ²)	73.5	
$\Delta \dot{H}_{Total Air}$ (lb)	81.52	
Air Rate (lb/min)	9.65	
$\Delta P_{Annubar}$ (in. H_2O)		
$T_{Annubar}$ (°R)		
$P_{Annubar}$ (lb/in ² a)		
$\rho_{Bleed Air}$ (lb/ft ³)		
$\dot{H}_{Bleed Air}$ (lb/min)		
$\dot{H}_{Pulse Air}$ (lb/min)		
$P_{Sparger}$ (lb/in ² g)	6.5	
Timer (on/off) (s)	1.25/1.13	
Volume (Air) (sft ³ /min)	128.82	
Material Rate ⁺ (lb/h)	26.0445	
Transport Ratio (air)(lb/sft ³)	3.37	

Notes

*Assumed
⁺Sample average
 based on recycle rate +
 (3600)($\Delta \dot{H}_{bed (reg.)}$)/ Θ_{Op}

Data Set: Case W

	Gasifier	Regenerator	Notes
<u>Bypass</u>			
ΔP_o (in. H_2O)			
P_1 (lb/in ² a)			
T_1 (°R)			
$P_{Fan Exit}$ (lb/in ² a)			
$T_{Fan Exit}$ (°R)			
μ (cp)			
γ			
$\dot{Q}_{Bypass}$ (lb/s)			
$\dot{M}_{Bypass}$ (lb/h)			
<u>Beds</u>			
Amps	155	160	
$\dot{M}_{Total}$ (lb/h)			
$\dot{M}_{Fluidizing}$ (lb/h)			
T_{Plenum} (°R)	376		
P_{Plenum} (lb/in ² a)			
ρ_{Plenum} (lb/ft ³)			
V_{Plenum} (ft/s)			
P_{Top} (lb/in ² a)			
ρ_{Top} (lb/ft ³)			
V_{Top} (ft/s)			
Display (start/end)	1134/1236	1247/1147	
Bed Wt. (start/end) (lb)	1969/2297	2341/1941	
Bed Ht. (start/end) (in.)	24/26	24/21	
ρ_{Bed} (start/end) (lb/ft ³)	102/109	121/115	
$\odot_{Op}$ (s)	694		
<u>Spargers</u>			
T_{Tank} (°R)	530*		
P_{Tank} (start/end) (lb/in ² g)	100/25		
ΔP_{Tank} (lb/in ²)	75		
$\dot{M}_{Total Air}$ (lb)	83.18		
Air Rate (lb/min)	7.19		
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)			
$P_{Sparger}$ (lb/in ² g)	7.3		
Timer (on/off) (s)			
Volume (Air) (ft ³ /min)	96.03		
Material Rate (lb/h)	22,473†		
Transport Ratio (air) (lb/ft ³)	3.90		

*Assumed
 †Sample average
 ‡Based on recycle rate +
 (3600)($\Delta \rho_{bed (reg.)}$)/ θ_{Op}

Data Set: Case X

	<u>Gasifier</u>	<u>Regenerator</u>
<u>Bypass</u>		
ΔP_o (in. H_2O)		
P_1 (lb/in ² a)		
T_1 (°R)		
$P_{Fan Exit}$ (lb/in ² a)		
$T_{Fan Exit}$ (°R)		
μ (cp)		
γ		
$\dot{Q}_{Bypass}$ (lb/s)		
$\dot{M}_{Bypass}$ (lb/h)		
<u>Beds</u>		
Amps	155	162
$\dot{M}_{Total}$ (lb/h)		
$\dot{M}_{Fluidizing}$ (lb/h)		
T_{Plenum} (°R)	581	
P_{Plenum} (lb/in ² a)		
ρ_{Plenum} (lb/ft ³)		
V_{Plenum} (ft/s)		
P_{Top} (lb/in ² a)		
ρ_{Top} (lb/ft ³)		
V_{Top} (ft/s)		
Display (start/end)	1165/1212	1216/1148
Bed Wt. (start/end) (lb)	2013/2201	2217/1945
Bed Ht. (start/end) (in.)	23/27	25/21
ρ_{Bed} (start/end) (lb/ft ³)	108/101	110/115
Θ_{Op} (s)	649	
<u>Spargers</u>		
T_{Tank} (°R)	530*	
P_{Tank} (start/end) (lb/in ² g)	99/25	
ΔP_{Tank} (lb/in ²)	74	
$\Delta \dot{M}_{Total Air}$ (lb)	82.07	
Air Rate (lb/min)	7.59	
$\Delta P_{Annubar}$ (in. H_2O)		
$T_{Annubar}$ (°R)		
$P_{Annubar}$ (lb/in ² a)		
$\rho_{Bleed Air}$ (lb/ft ³)		
$\dot{M}_{Bleed Air}$ (lb/min)		
$\dot{M}_{Pulse Air}$ (lb/min)		
$P_{Sparger}$ (lb/in ² g)	7.3	
Timer (on/off) (s)		
Volume (Air) (sft ³ /min)	101.32	
Material Rate ⁺ (lb/h)	22,989 ⁺	
Transport Ratio (air)(lb/sft ³)	3.78	

Notes

*Assumed
 T Sample average
 $\dot{M}$ Based on recycle rate +
 (3600)($\Delta \dot{M}_{bed (reg.)}$)/ Θ_{Op}

Data Set: Case Y

	<u>Gasifier</u>	<u>Regenerator</u>	
<u>Bypass</u>			<u>Notes</u>
ΔP_o (in. H_2O)			*Assumed
P_1 (lb/in ² a)			SAir rate assumed equal to
T_1 (°R)			that of Case X
$P_{Fan Exit}$ (lb/in ² a)			†Sample average
$T_{Fan Exit}$ (°R)			‡Based on recycle rate +
μ (cp)			(3600)($\Delta H_{bed (reg.)}$)/ θ_{Op}
γ			
$\dot{Q}_{Bypass}$ (lb/s)			
$\dot{M}_{Bypass}$ (lb/h)			
<u>Be</u> Amps	153	162	
$\dot{M}_{Total}$ (lb/h)			
$\dot{M}_{Fluidizing}$ (lb/h)			
T_{Plenum} (°R)	590		
P_{Plenum} (lb/in ² a)			
ρ_{Plenum} (lb/ft ³)			
V_{Plenum} (ft/s)			
P_{Top} (lb/in ² a)			
ρ_{Top} (lb/ft ³)			
V_{Top} (ft/s)			
Display (start/end)	1219/1229	1256/1120	
Bed Wt. (start/end) (lb)	2229/2269	2377/1841	
Bed Ht. (start/end) (in.)	24/27	24/21	
ρ_{Bed} (start/end) (lb/ft ³)	115/104	123/109	
θ_{Op} (s)	1800		
<u>Spargers</u>			
T_{Tank} (°R)	530*		
P_{Tank} (start/end) (lb/in ² g)			
ΔP_{Tank} (lb/in ²)			
$\Delta \dot{M}_{Total Air}$ (lb)			
Air Rate (lb/min)	7.595		
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² g)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)			
$P_{Sparger}$ (lb/in ² g)			
Timer (on/off) (s)			
Volume (Air) (scf ³ /min)	101.32		
Material Rate [†] (lb/h)	22,072†		
Transport Ratio (air) (lb/scf ³)	3.63		

APPENDIX E
CALCULATION SHEETS FOR THE PRIMARY GASIFIER-REGENERATOR
BED-MATERIAL TRANSFER SLOT--FOURTH GENERATION--FREQUENCY
TESTS WITHOUT SPARGER BLEED AIR

Data Set: FO

	<u>Gasifier</u>	<u>Regenerator</u>	
<u>Bypass</u> ΔP_0 (in. H_2O)	78.18	72.57	
P_1 (lb/in ² a)	16.3	16.2	
T_1 (°R)	584	580	<u>Note</u>
$P_{Fan Exit}$ (lb/in ² a)	17.3	17.3	†Sample average
$T_{Fan Exit}$ (°R)	589	578	
μ (cp)	0.01934	0.01924	
γ	0.96132	0.96386	
$\dot{M}_{Bypass}$ (lb/s)	5.914	5.715	
$\dot{M}_{Bypass}$ (lb/h)	21,290	20,375	
<u>Beds</u> Amps	133	160	
$\dot{M}_{Total}$ (lb/h)	35,646	36,796	
$\dot{M}_{Fluidizing}$ (lb/h)	14,356	16,221	
T_{Plenum} (°R)	583	583	
P_{Plenum} (lb/in ² a)	16.6	16.6	
ρ_{Plenum} (lb/ft ³)	0.0767	0.0768	
V_{Plenum} (ft/s)	5.36	6.05	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0681	0.0681	
V_{Top} (ft/s)	6.05	6.84	
Display (start/end)	1208/1256	1110/1054	
Bed Wt. (start/end) (lb)	2185/2377	1793/1580	
Bed Ht. (start/end) (in.)	27/25	20/19	
ρ_{Bed} (start/end) (lb/ft ³)	100/118	111/103	
θ_{Op} (s)	690		
<u>Spargers</u> T_{Tank} (°R)		540	
P_{Tank} (start/end) (lb/in ² g)		98/25	
ΔP_{Tank} (lb/in ²)		73	
$\dot{M}_{Total Air}$ (lb)		79.46	
Air Rate (lb/min)		6.91	
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)		6.91	
$P_{Sparger}$ (lb/in ² g)		7.5	
Timer (on/off) (s)		1.25/1.15	
Volume (Air) (ft ³ /min)		92.27	
Material Rate (lb/h)		21,120	
Transport Ratio (air) (lb/ft ³)		3.81	

Data Set: FOR₁

	<u>Gasifier</u>	<u>Regenerator</u>	
<u>Bypass</u>	ΔP_o (in. H ₂ O)	77.88	72.57
	P_1 (lb/in ² a)	16.3	16.1
	T_1 (°R)	386	580
	$P_{Fan Exit}$ (lb/in ² a)	17.3	17.3
	$T_{Fan Exit}$ (°R)	590	578
	μ (cp)	0.01939	0.01924
	γ	0.96147	0.96383
	$\dot{W}_{Bypass}$ (lb/s)	3.893	5.697
	$\dot{M}_{Bypass}$ (lb/h)	21,216	20,511
<u>Beds</u>	Amps	155	175
	$\dot{M}_{Total}$ (lb/h)	37,348	42,167
	$\dot{M}_{Fluidizing}$ (lb/h)	16,132	21,656
	T_{Plenum} (°R)	582	582
	P_{Plenum} (lb/in ² a)	16.8	16.9
	ρ_{Plenum} (lb/ft ³)	0.0781	0.0783
	V_{Plenum} (ft/s)	5.94	7.92
	P_{Top} (lb/in ² a)	14.7	14.7
	ρ_{Top} (lb/ft ³)	0.0682	0.0682
	V_{Top} (ft/s)	6.79	9.11
	Display (start/end)	1135/1200	1147/1111
	Bed Wt. (start/end) (lb)	1893/2153	1941/1797
	Bed Ht. (start/end) (in.)	25	22
	ρ_{Bed} (start/end) (lb/ft ³)	94	109
	θ_{Op} (s)		992
<u>Spargers</u>	T_{Tank} (°R)		340
	P_{Tank} (start/end) (lb/in ² g)		99/25
	ΔP_{Tank} (lb/in ²)		74
	$\Delta \dot{M}_{Total Air}$ (lb)		80.55
	Air Rate (lb/min)		4.87
	$\Delta P_{Annubar}$ (in. H ₂ O)		
	$T_{Annubar}$ (°R)		
	$P_{Annubar}$ (lb/in ² a)		
	$\rho_{Bleed Air}$ (lb/ft ³)		
	$\dot{M}_{Bleed Air}$ (lb/min)		
	$\dot{M}_{Pulse Air}$ (lb/min)		4.87
	$P_{Sparger}$ (lb/in ² g)		7.0
	Timer (on/off) (s)		1.25/1.15
	Volume (Air) (sft ³ /min)		65.06
	Material Rate ⁺ (lb/h)		21,240
	Transport Ratio (air) (lb/sft ³)		5.44

Notes

+Sample average

Data Set: FOR₂

	<u>Gasifier</u>	<u>Regenerator</u>	
<u>Bypass</u> ΔP_0 (in. H ₂ O)	79.63	74.05	
P_1 (lb/in ² a)	16.3	16.2	
T_1 (°R)	574	568	<u>Note</u>
$P_{Fan Exit}$ (lb/in ² a)	17.4	17.3	†Sample average
$T_{Fan Exit}$ (°R)	578	567	
μ (cp)	0.01908	0.01893	
γ	0.96067	0.96315	
$\dot{Q}_{Bypass}$ (lb/s)	6.016	5.829	
$\dot{N}_{Bypass}$ (lb/h)	21,659	20,984	
<u>Beds</u> $\dot{M}_{Total}$ (lb/h)	150	162	
$\dot{N}_{Fluidizing}$ (lb/h)	34,148	36,879	
T_{Plenum} (°R)	12,489	15,893	
P_{Plenum} (lb/in ² a)	570	570	
ρ_{Plenum} (lb/ft ³)	16.6	16.6	
V_{Plenum} (ft/s)	0.0786	0.0786	
P_{Top} (lb/in ² a)	4.56	5.80	
ρ_{Top} (lb/ft ³)	14.7	14.7	
V_{Top} (ft/s)	0.0696	0.0696	
Display (start/end)	5.15	6.55	
Bed Wt. (start/end) (lb)	1163/1162	1219/1210	
Bed Ht. (start/end) (in.)	2005/2001	2229/2193	
ρ_{Bed} (start/end) (lb/ft ³)	21/20	24/24	
ϕ_{Op} (s)	118/124	115/113	
<u>Spargers</u> T_{Tank} (°R)		928.2	
P_{Tank} (start/end) (lb/in ² g)		542	
ΔP_{Tank} (lb/in ²)		98.5/26.0	
$\Delta \dot{N}_{Total Air}$ (lb)		72.5	
Air Rate (lb/min)		78.63	
$\Delta P_{Annubar}$ (in. H ₂ O)		5.08	
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{N}_{Bleed Air}$ (lb/min)			
$\dot{N}_{Pulse Air}$ (lb/min)			
$P_{Sparger}$ (lb/in ² g)		5.08	
Timer (on/off) (s)		7.0	
Volume (Air) (ft ³ /min)		1.25/1.15	
Material Rate ⁺ (lb/h)		67.87	
Transport Ratio (air) (lb/ft ³)		18,920	
		4.65	

Data Set: F1

	Casifier	Regenerator	
<u>Bypass</u>	78.18	73.46	
ΔP_o (in. H_2O)			
P_1 (lb/in ² a)	16.3	16.2	
T_1 (°R)	580	575	Note
$P_{Fan Exit}$ (lb/in ² a)	17.3	17.3	†Sample average
$T_{Fan Exit}$ (°R)	586	574	
μ (cp)	0.01924	0.01911	
γ	0.96135	0.96344	
$\dot{Q}_{Bypass}$ (lb/s)	5.934	5.772	
$\dot{H}_{Bypass}$ (lb/h)	21,363	20,780	
<u>Beds</u>			
Amps	150	165	
$\dot{H}_{Total}$ (lb/h)	34,496	37,946	
$\dot{H}_{Fluidizing}$ (lb/h)	13,133	17,166	
T_{Plenum} (°R)	573	574	
P_{Plenum} (lb/in ² a)	16.6	16.6	
ρ_{Plenum} (lb/ft ³)	0.0780	0.0779	
V_{Plenum} (ft/s)	4.82	6.31	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0693	0.0692	
V_{Top} (ft/s)	3.44	7.12	
Display (start/end)	1165/1145	1181/1191	
Bed Wt. (start/end) (lb)	2013/1933	2077/2117	
Bed Ht. (start/end) (in.)	22/21	23/25	
ρ_{Bed} (start/end) (lb/ft ³)	113/114	112/105	
ϕ_{Op} (s)		387.7	
<u>Spargers</u>			
T_{Tank} (°R)		538	
P_{Tank} (start/end) (lb/in ² g)		98/81	
ΔP_{Tank} (lb/in ²)		17	
$\Delta \dot{H}_{Total Air}$ (lb)		18.57	
Air Rate (lb/min)		2.87	
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{H}_{Bleed Air}$ (lb/min)			
$\dot{H}_{Pulse Air}$ (lb/min)		2.87	
$P_{Sparger}$ (lb/in ² g)		7.2	
Timer (on/off) (s)		1.25/3.95	
Volume (Air) (sft ³ /min)		38.38	
Material Rate ⁺ (lb/h)		14,940	
Transport Ratio (air) (lb/sft ³)		6.49	

Data Set: F1R₁

	Gasifier	Regenerator	
<u>Bypass</u>	79.63	74.93	
ΔP_0 (in. H ₂ O)			
P_1 (lb/in ² a)	16.3	16.2	
T_1 (°R)	574	567	<u>Note</u>
$P_{Fan Exit}$ (lb/in ² a)	17.3	17.3	†Sample average
$T_{Fan Exit}$ (°R)	578	566	
μ (cp)	0.01908	0.01890	
γ	0.96067	0.96276	
$\dot{Q}_{Bypass}$ (lb/s)	6.016	5.866	
$\dot{M}_{Bypass}$ (lb/h)	21.659	21.118	
<u>Beds</u>			
Amps	147	167	
$\dot{M}_{Total}$ (lb/h)	33,693	38,277	
$\dot{M}_{Fluidizing}$ (lb/h)	12,034	17,139	
T_{Plenum} (°R)	571	570	
P_{Plenum} (lb/in ² a)	16.6	16.6	
ρ_{Plenum} (lb/ft ³)	0.0784	0.0785	
V_{Plenum} (ft/s)	4.40	6.26	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0693	0.0697	
V_{Top} (ft/s)	4.97	7.07	
Display (start/end)	1184/1173	1216/1161	
Bed Wt. (start/end) (lb)	2089/2045	2217/1997	
Bed Ht. (start/end) (in.)	20/23	24/22.25	
ρ_{Bed} (start/end) (lb/ft ³)	129/110	114/111	
ϕ_{Op} (s)		1200	
<u>Spargers</u>			
T_{Tank} (°R)		540	
P_{Tank} (start/end) (lb/in ² g)		98/41	
ΔP_{Tank} (lb/in ²)		57	
$\Delta \dot{M}_{Total Air}$ (lb)		62.05	
Air Rate (lb/min)		3.10	
$\Delta P_{Annubar}$ (in. H ₂ O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)		3.10	
$P_{Sparger}$ (lb/in ² g)		7.0	
Timer (on/off) (s)		1.25/3.95	
Volume (Air) (sft ³ /min)		41.43	
Material Rate [†] (lb/h)		18,720	
Transport Ratio (air) (lb/sft ³)		7.53	

Data Set: FLR₂

		Gasifier	Regenerator	
<u>Bypass</u>	ΔP_0 (in. H ₂ O)	78.18	72.87	
	P_1 (lb/in ² a)	16.3	16.1	
	T_1 (°R)	580	575	<u>Note</u>
	$P_{\text{Fan Exit}}$ (lb/in ² a)	17.3	17.3	†Sample average
	$T_{\text{Fan Exit}}$ (°R)	556	574	
	μ (cp)	0.01924	0.01911	
	η	0.96130	0.96362	
	$\dot{Q}_{\text{Bypass}}$ (lb/s)	5.934	5.733	
	$\dot{M}_{\text{Bypass}}$ (lb/h)	21,362	20,637	
<u>Beds</u>	Amps	147	165	
	$\dot{M}_{\text{Total}}$ (lb/h)	33,465	37,562	
	$\dot{M}_{\text{Fluidizing}}$ (lb/h)	12,103	16,925	
	T_{Plenum} (°R)	578	578	
	P_{Plenum} (lb/in ² a)	16.6	16.6	
	ρ_{Plenum} (lb/ft ³)	0.0773	0.0773	
	V_{Plenum} (ft/s)	4.48	6.26	
	P_{Top} (lb/in ² a)	14.7	14.7	
	ρ_{Top} (lb/ft ³)	0.0687	0.0687	
	V_{Top} (ft/s)	5.06	7.07	
	Display (start/end)	1158/1145	1200/1219	
	Bed Wt. (start/end) (lb)	1985/1933	2153/2229	
	Bed Ht. (start/end) (in.)	21/21	25/24	
	ρ_{Bed} (start/end) (lb/ft ³)	117/114	107/115	
	ϕ_{Op} (s)		1200	
<u>Spargers</u>	T_{Tank} (°R)		538	
	P_{Tank} (start/end) (lb/in ² g)		97.5/43	
	ΔP_{Tank} (lb/in ²)		54.5	
	$\Delta \dot{M}_{\text{Total Air}}$ (lb)		59.55	
	Air Rate (lb/min)		2.98	
	$\Delta P_{\text{Annubar}}$ (in. H ₂ O)			
	T_{Annubar} (°R)			
	P_{Annubar} (lb/in ² a)			
	$\rho_{\text{Bleed Air}}$ (lb/ft ³)			
	$\dot{M}_{\text{Bleed Air}}$ (lb/min)			
	$\dot{M}_{\text{Pulse Air}}$ (lb/min)		2.98	
	P_{Sparger} (lb/in ² g)		7.1	
	Timer (on/off) (s)		1.25/3.95	
	Volume (Air) (sft ³ /min)		39.76	
	Material Rate [†] (lb/h)		18,800	
	Transport Ratio (air) (lb/sft ³)		7.88	

Data Set: F2

	Gasifier	Regenerator	
<u>Bypass</u>			
ΔP_o (in. H_2O)	78.47	73.46	
P_1 (lb/in ² a)	16.3	16.1	
T_1 (°R)	578	574	Note
$P_{Fan Exit}$ (lb/in ² a)	17.3	17.3	†Sample average
$T_{Fan Exit}$ (°R)	584	574	
μ (cp)	0.01919	0.01908	
γ	0.96120	0.96335	
$\dot{M}_{Bypass}$ (lb/s)	3.954	5.759	
$\dot{M}_{Bypass}$ (lb/h)	21,436	20,732	
<u>Beds</u>			
Amps	150	160	
$\dot{M}_{Total}$ (lb/h)	33,912	36,172	
$\dot{M}_{Fluidizing}$ (lb/h)	12,476	15,440	
T_{Plenum} (°R)	577	577	
P_{Plenum} (lb/in ² a)	16.7	16.7	
ρ_{Plenum} (lb/ft ³)	0.0782	0.0782	
V_{Plenum} (ft/s)	4.58	5.67	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0688	0.0688	
V_{Top} (ft/s)	5.20	6.44	
Display (start/end)	1232/1195	1018/1156	
Bed Wt. (start/end) (lb)	2281/2133	1510/1977	
Bed Ht. (start/end) (in.)	26/22	18/22	
ρ_{Bed} (start/end) (lb/ft ³)	109/120	104/111	
G_{Op} (s)		1200	
<u>Spargers</u>			
T_{Tank} (°R)		538	
P_{Tank} (start/end) (lb/in ² g)		99/31	
ΔP_{Tank} (lb/in ²)		68	
$\dot{M}_{Total Air}$ (lb)		74.30	
Air Rate (lb/min)		3.71	
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)		3.71	
$P_{Sparger}$ (lb/in ² g)		7.0	
Timer (on/off) (s)		1.23/5.45	
Volume (Air) (ft ³ /min)		49.61	
Material Rate [†] (lb/h)		20,040	
Transport Ratio (air) (lb/sft ³)		6.73	

Data Set: F2R₁

	Gasifier	Regenerator	
<u>Bypass</u>			
ΔP_0 (in. H ₂ O)	78.18	73.16	
P_1 (lb/in ² a)	16.3	16.1	
T_1 (°R)	585	580	<u>Note</u>
$P_{Fan Exit}$ (lb/in ² a)	17.3	17.3	†Sample average
$T_{Fan Exit}$ (°R)	592	578	
μ (cp)	0.01937	0.01924	
γ	0.96132	0.96354	
$\dot{Q}_{Bypass}$ (lb/s)	5.909	5.719	
$\dot{H}_{Bypass}$ (lb/h)	21,272	20,588	
<u>Beds</u>			
Amps	150	140	
$\dot{H}_{Total}$ (lb/h)	33,912	36,172	
$\dot{H}_{Fluidizing}$ (lb/h)	12,640	15,584	
T_{Plenum} (°R)	583	582	
P_{Plenum} (lb/in ² a)	16.5	16.5	
ρ_{Plenum} (lb/ft ³)	0.0764	0.0765	
V_{Plenum} (ft/s)	4.75	5.84	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0681	0.0682	
V_{Top} (ft/s)	5.33	6.56	
Display (start/end)	1168	1243	
Bed Wt. (start/end) (lb)	2025	2325	
Bed Ht. (start/end) (in.)	19/19	24/24.5	
ρ_{Bed} (start/end) (lb/ft ³)	132	120	
ϕ_{Op} (s)		1200	
<u>Spargers</u>			
T_{Tank} (°R)		540	
P_{Tank} (start/end) (lb/in ² g)		99/56	
ΔP_{Tank} (lb/in ²)		43	
$\Delta \dot{H}_{Total Air}$ (lb)		46.81	
Air Rate (lb/min)		2.34	
$\Delta P_{Annubar}$ (in. H ₂ O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{H}_{Bleed Air}$ (lb/min)			
$\dot{H}_{Pulse Air}$ (lb/min)		2.34	
$P_{Sparger}$ (lb/in ² g)		7.0	
Timer (on/off)(s)		1.25/5.45	
Volume (Air) (sft ³ /min)		31.25	
Material Rate ⁺ (lb/h)		18,000	
Transport Ratio (air)(lb/sft ³)		9.60	

Data Set: F3

	<u>Gasifier</u>	<u>Regenerator</u>	
<u>Bypass</u>	ΔP_0 (in. H_2O)	78.77	73.75
	P_1 (lb/in ² a)	16.3	16.2
	T_1 (°R)	580	575
	$P_{Fan Exit}$ (lb/in ² a)	17.3	17.3
	$T_{Fan Exit}$ (°R)	585	574
	μ (cp)	0.01924	0.01911
	γ	0.96106	0.96330
	$\dot{Q}_{Bypass}$ (lb/s)	3.955	5.783
	$\dot{Q}_{Bypass}$ (lb/h)	21,437	20,818
<u>Beds</u>	Amps	150	160
	$\dot{Q}_{Total}$ (lb/h)	33,912	36,172
	$\dot{Q}_{Fluidizing}$ (lb/h)	12,475	15,354
	T_{Plenum} (°R)	578	577
	P_{Plenum} (lb/in ² a)	16.5	16.5
	ρ_{Plenum} (lb/ft ³)	0.0771	0.0772
	V_{Plenum} (ft/s)	4.64	5.71
	P_{Top} (lb/in ² a)	14.7	14.7
	ρ_{Top} (lb/ft ³)	0.0687	0.0688
	V_{Top} (ft/s)	5.21	6.40
	Display (start/end)	1128/1143	1214/1229
	Bed Wt. (start/end) (lb)	1865/1925	2209/2269
	Bed Ht. (start/end) (in.)	21/19	23.5/24
	ρ_{Bed} (start/end) (lb/ft ³)	110/126	117/117
	$\odot_{Op}$ (s)		1200
<u>Spargers</u>	T_{Tank} (°R)		540
	P_{Tank} (start/end) (lb/in ² g)		98/52.5
	ΔP_{Tank} (lb/in ²)		43.5
	$\Delta \dot{Q}_{Total Air}$ (lb)		49.53
	Air Rate (lb/min)		2.48
	$\Delta P_{Annubar}$ (in. H_2O)		
	$T_{Annubar}$ (°R)		
	$P_{Annubar}$ (lb/in ² a)		
	$\rho_{Bleed Air}$ (lb/ft ³)		
	$\dot{Q}_{Bleed Air}$ (lb/min)		
	$\dot{Q}_{Pulse Air}$ (lb/min)		2.48
	$P_{Sparger}$ (lb/in ² g)		7.0
	Timer (on/off)(s)		1.25/7.55
	Volume (Air) (sft ³ /min)		33.07
	Material Rate ⁺ (lb/h)		18,160
	Transport Ratio (air) (lb/sft ³)		9.15

Note

+Sample average

Data Set: F3R₁

	Gasifier	Regenerator	
<u>Bypass</u>			
ΔP_0 (in. H ₂ O)	78.77	72.87	
P_1 (lb/in ² a)	16.3	16.2	
T_1 (°R)	583	578	<u>Note</u>
$P_{\text{Fan Exit}}$ (lb/in ² a)	17.3	17.3	†Sample average
$T_{\text{Fan Exit}}$ (°R)	587	577	
μ (cp)	0.01932	0.01919	
γ	0.96103	0.96371	
$\dot{Q}_{\text{Bypass}}$ (lb/s)	3.939	5.736	
$\dot{M}_{\text{Bypass}}$ (lb/h)	21,381	20,649	
<u>Beds</u>			
Amps	155	157	
$\dot{M}_{\text{Total}}$ (lb/h)	35,286	35,741	
$\dot{M}_{\text{Fluidizing}}$ (lb/h)	13,905	15,092	
T_{Plenum} (°R)	582	581	
P_{Plenum} (lb/in ² a)	16.5	16.5	
ρ_{Plenum} (lb/ft ³)	0.0767	0.0769	
V_{Plenum} (ft/s)	5.21	5.65	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0682	0.0683	
V_{Top} (ft/s)	5.85	6.34	
Display (start/end)	1124/1153	1249/1196	
Bed Wt. (start/end) (lb)	1849/1965	2349/2137	
Bed Ht. (start/end) (in.)	19/20	24.5/22.5	
ρ_{Bed} (start/end) (lb/ft ³)	121/122	119/118	
ϕ_{Op} (s)		1700	
<u>Spargers</u>			
T_{Tank} (°R)		546	
P_{Tank} (start/end) (lb/in ² g)		98/42.5	
ΔP_{Tank} (lb/in ²)		55.5	
$\Delta \dot{M}_{\text{Total Air}}$ (lb)		59.74	
Air Rate (lb/min)		2.99	
$\Delta P_{\text{Annubar}}$ (in. H ₂ O)			
T_{Annubar} (°R)			
P_{Annubar} (lb/in ² a)			
$\dot{C}_{\text{Bleed Air}}$ (lb/ft ³)			
$\dot{M}_{\text{Bleed Air}}$ (lb/min)			
$\dot{M}_{\text{Pulse Air}}$ (lb/min)		2.99	
P_{Sparger} (lb/in ² g)		7.0	
Timer (on/off) (s)		1.25/7.55	
Volume (Air) (sft ³ /min)		39.89	
Material Rate ⁺ (lb/h)		18,840	
Transport Ratio (air)(lb/sft ³)		7.87	

Data Set: F4

	Bypass	Gasifier	Regenerator	
	ΔP_o (in. H_2O)	80.54	75.23	
	P_1 (lb/in ² a)	16.3	16.2	
	T_1 (°R)	573	568	<u>Note</u>
	$P_{Fan Exit}$ (lb/in ² a)	17.4	17.4	†Sample average
	$T_{Fan Exit}$ (°R)	577	566	
	μ (cp)	0.01906	0.01893	
	η	0.96028	0.96259	
	$\dot{Q}_{Bypass}$ (lb/s)	6.053	5.872	
	$\dot{M}_{Bypass}$ (lb/h)	21,789	21,138	
<u>Beds</u>	Amps	155	162	
	$\dot{M}_{Total}$ (lb/h)	35,882	37,503	
	$\dot{M}_{Fluidizing}$ (lb/h)	14,093	16,365	
	T_{Plenum} (°R)	568	568	
	P_{Plenum} (lb/in ² a)	16.6	16.6	
	ρ_{Plenum} (lb/ft ³)	0.0787	0.0787	
	V_{Plenum} (ft/s)	5.12	5.95	
	P_{Top} (lb/in ² a)	14.7	14.7	
	ρ_{Top} (lb/ft ³)	0.0699	0.0699	
	V_{Top} (ft/s)	5.79	6.72	
	Display (start/end)	1153/1165	1196/1168	
	Bed Wt. (start/end) (lb)	1965/2013	2137/2025	
	Bed Ht. (start/end) (in.)	20/22	22.5/22.75	
	ρ_{Bed} (start/end) (lb/ft ³)	122/113	118/110	
	C_{Op} (s)		1200	
<u>Spargers</u>	T_{Tank} (°R)		535	
	P_{Tank} (start/end) (lb/in ² g)		96.5/53	
	ΔP_{Tank} (lb/in ²)		43.5	
	$\dot{M}_{Total Air}$ (lb)		47.79	
	Air Rate (lb/min)		2.39	
	$\Delta P_{Annubar}$ (in. H_2O)			
	$T_{Annubar}$ (°R)			
	$P_{Annubar}$ (lb/in ² a)			
	$\rho_{Bleed Air}$ (lb/ft ³)			
	$\dot{M}_{Bleed Air}$ (lb/min)			
	$\dot{M}_{Pulse Air}$ (lb/min)		2.39	
	$P_{Sparger}$ (lb/in ² g)		7.1	
	Timer (on/off) (s)		1.25/9.95	
	Volume (Air) (sft ³ /min)		31.91	
	Material Rate ⁺ (lb/h)		18,000	
	Transport Ratio (air)(lb/sft ³)		9.40	

Data Set: F4R₁

		Casifier	Regenerator	
<u>Bypass</u>	ΔP_o (in. H ₂ O)	79.36	73.46	
	P_1 (lb/in ² a)	16.3	16.1	
	T_1 (°R)	575	572	<u>Note</u>
	$P_{Fan Exit}$ (lb/in ² a)	17.4	17.3	†Sample average
	$T_{Fan Exit}$ (°R)	578	568	
	μ (cp)	0.01911	0.01903	
	Y	0.96082	0.96339	
	$\dot{Q}_{Bypass}$ (lb/s)	6.001	5.769	
	$\dot{M}_{Bypass}$ (lb/h)	21,604	20,769	
<u>Beds</u>	Amps	157	160	
	$\dot{M}_{Total}$ (lb/h)	36,345	37,040	
	$\dot{M}_{Fluidizing}$ (lb/h)	14,741	16,271	
	T_{Plenum} (°R)	571	570	
	P_{Plenum} (lb/in ² a)	16.6	16.6	
	ρ_{Plenum} (lb/ft ³)	0.0784	0.0785	
	V_{Plenum} (ft/s)	5.39	5.94	
	P_{Top} (lb/in ² a)	14.7	14.7	
	ρ_{Top} (lb/ft ³)	0.0695	0.0697	
	V_{Top} (ft/s)	6.08	6.70	
	Display (start/end)	1126	1214	
	Bed Wt. (start/end) (lb)	1857	2209	
	Bed Ht. (start/end) (in.)	21	23	
	ρ_{Bed} (start/end) (lb/ft ³)	110	119	
	$\odot_{Op}$ (s)		1200	
<u>Spargers</u>	T_{Tank} (°R)		535	
	P_{Tank} (start/end) (lb/in ² g)		90/59	
	ΔP_{Tank} (lb/in ²)		31	
	$\dot{M}_{Total Air}$ (lb)		34.06	
	Air Rate (lb/min)		1.70	
	$\Delta P_{Annubar}$ (in. H ₂ O)			
	$T_{Annubar}$ (°R)			
	$P_{Annubar}$ (lb/in ² a)			
	$\rho_{Bleed Air}$ (lb/ft ³)			
	$\dot{M}_{Bleed Air}$ (lb/min)			
	$\dot{M}_{Pulse Air}$ (lb/min)		1.70	
	$P_{Sparger}$ (lb/in ² g)		8.0	
	Timer (on/off) (s)		1.25/9.95	
	Volume (Air) (sft ³ /min)		22.74	
	Material Rate (lb/h)		11,340	
	Transport Ratio (air) (lb/sft ³)		8.31	

Data Set: F4R₂

	Gasifier	Regenerator	
<u>Bypass</u>			
ΔP_0 (in. H ₂ O)	80.83	74.93	
P_1 (lb/in ² a)	16.3	16.2	
T_1 (*R)	568	563	<u>Notes</u>
$P_{Fan Exit}$ (lb/in ² a)	17.4	17.3	*Possibly in error
$T_{Fan Exit}$ (*R)	573	562	†Sample average
μ (cp)	0.01893	0.01880	
γ	0.96011	0.96276	
$\dot{W}_{Bypass}$ (lb/s)	6.089	5.887	
$\dot{M}_{Bypass}$ (lb/h)	21,920	21,193	
<u>Beds</u>			
Amps	155	165	
$\dot{M}_{Total}$ (lb/h)	36,231	38,568	
$\dot{M}_{Fluidizing}$ (lb/h)	14,311	17,375	
T_{Plenum} (*R)	566	565	
P_{Plenum} (lb/in ² a)	16.6	16.6	
ρ_{Plenum} (lb/ft ³)	0.0790	0.0791	
V_{Plenum} (ft/s)	5.20	6.30	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0701	0.0702	
V_{Top} (ft/s)	5.85	7.10	
Display (start/end)	1230/1187	1165/1200	
Bed Wt. (start/end) (lb)	2273/2101	2013/2153	
Bed Ht. (start/end) (in.)	22/21	21/22	
ρ_{Bed} (start/end) (lb/ft ³)	128/124	119/121	
ϕ_{Op} (s)	900		
<u>Spargers</u>			
T_{Tank} (*R)	535		
P_{Tank} (start/end) (lb/in ² g)	94/66*		
ΔP_{Tank} (lb/in ²)	28		
$\dot{M}_{Total Air}$ (lb)	30.76		
Air Rate (lb/min)	2.05		
$\Delta P_{Annubar}$ (in. H ₂ O)			
$T_{Annubar}$ (*R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)	2.05		
$P_{Sparger}$ (lb/in ² g)	7.5		
Timer (on/off) (s)	1.25/9.95		
Volume (Air) (sft ³ /min)	27.39		
Material Rate (lb/h)	11,850		
Transport Ratio (air) (lb/sft ³)	7.21		

Data Set: F4R₃

	Gasifier	Regenerator	
<u>Bypass</u>			
ΔP_o (in. H ₂ O)	80.24	74.05	
P_1 (lb/in ² a)	16.3	16.2	
T_1 (°R)	580	574	
$P_{Fan Exit}$ (lb/in ² a)	17.4	17.3	
$T_{Fan Exit}$ (°R)	583	572	
μ (cp)	0.01924	0.01908	
Y	0.96038	0.96315	
$\dot{Q}_{Bypass}$ (lb/a)	6.006	3.799	
$\dot{M}_{Bypass}$ (lb/h)	21,620	20,875	
<u>Beds</u>			
Amps	150	160	
$\dot{M}_{Total}$ (lb/h)	33,912	36,172	
$\dot{M}_{Fluidizing}$ (lb/h)	12,292	15,297	
T_{Plenum} (°R)	582	573	
P_{Plenum} (lb/in ² a)	16.4	16.4	
ρ_{Plenum} (lb/ft ³)	0.0761	0.0773	
V_{Plenum} (ft/s)	4.63	5.68	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0682	0.0693	
V_{Top} (ft/s)	5.17	6.34	
Display (start/end)	1045/1020	1212/1267	
Bed Wt. (start/end) (lb)	1563/1514	2201/2421	
Bed Ht. (start/end) (in.)	18/17	24.5/26	
ρ_{Bed} (start/end) (lb/ft ³)	108/110	111/115	
Θ_{Op} (s)	1200		
<u>Spargers</u>			
T_{Tank} (°R)	536		
P_{Tank} (start/end) (lb/in ² g)	94,166*		
ΔP_{Tank} (lb/in ²)	28		
$\Delta \dot{M}_{Total Air}$ (lb)	30.71		
Air Rate (lb/min)	1.54		
$\Delta P_{Annubar}$ (in. H ₂ O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)	1.54		
$P_{Sparger}$ (lb/in ² g)	7		
Timer (on/off) (s)	1.25/9.95		
Volume (Air) (sft ³ /min)	20.50		
Material Rate (lb/h)	17,120		
Transport Ratio (air) (lb/sft ³)	13.92		

Notes

*Possibly in error
†Sample average

Data Set: F4R₄

		Casifier	Regenerator	
<u>Bypass</u>	ΔP_o (in. H ₂ O)	80.24	74.05	
	P_1 (lb/in ² a)	16.3	16.2	
	T_1 ("R)	578	572	Note
	$P_{Fan Exit}$ (lb/in ² a)	17.4	17.3	†Sample average
	$T_{Fan Exit}$ ("R)	583	572	
	u (cp)	0.01919	0.01903	
	Y	0.96038	0.96315	
	$\dot{Q}_{Bypass}$ (lb/s)	6.016	5.809	
	$\dot{Q}_{Bypass}$ (lb/h)	21,657	20,911	
<u>Beds</u>	Amps	150	160	
	$\dot{M}_{Total}$ (lb/h)	33,912	36,172	
	$\dot{M}_{Fluidizing}$ (lb/h)	12,255	15,261	
	T_{Plenum} ("R)	574	573	
	P_{Plenum} (lb/in ² a)	16.4	16.4	
	ρ_{Plenum} (lb/ft ³)	0.0772	0.0773	
	V_{Plenum} (ft/s)	4.56	5.67	
	P_{Top} (lb/in ² a)	14.7	14.7	
	ρ_{Top} (lb/ft ³)	0.0692	0.0693	
	V_{Top} (ft/s)	5.00	6.32	
	Display (start/end)	1165/1176	1167/1146	
	Bed Wt. (start/end) (lb)	2013/2057	2021/1937	
	Bed Wt. (start/end) (in.)	22	22.75	
	ρ_{Bed} (start/end) (lb/ft ³)	113	110	
	G_{Op} (s)		653	
<u>Spargers</u>	T_{Tank} ("R)		536	
	P_{Tank} (start/end) (lb/in ² g)		94/74	
	ΔP_{Tank} (lb/in ²)		20	
	$\dot{M}_{Total Air}$ (lb)		21.93	
	Air Rate (lb/min)		2.02	
	$\Delta P_{Annubar}$ (in. H ₂ O)			
	$T_{Annubar}$ ("R)			
	$P_{Annubar}$ (lb/in ² a)			
	$\rho_{Bleed Air}$ (lb/ft ³)			
	$\dot{M}_{Bleed Air}$ (lb/min)			
	$\dot{M}_{Pulse Air}$ (lb/min)		2.02	
	$P_{Sparger}$ (lb/in ² g)			
	Timer (on/off) (s)		1.25/9.95	
	Volume (Air) (sft ³ /min)		26.91	
	Material Rate ⁺ (lb/h)		17,160	
	Transport Ratio (air) (lb/sft ³)		10.63	

Data Set: F5

	Gasifier	Regenerator	
<u>Bypass</u>			
ΔP_o (in. H_2O)	78.47	73.46	
P_1 (lb/in ² a)	16.3	16.1	
T_1 ($^{\circ}R$)	580	572	<u>Note</u>
$P_{Fan Exit}$ (lb/in ² a)	17.3	17.3	+Sample average
$T_{Fan Exit}$ ($^{\circ}R$)	586	573	
μ (cp)	0.01924	0.01903	
γ	0.96118	0.96339	
$\dot{W}_{Bypass}$ (lb/s)	5.944	5.769	
$\dot{M}_{Bypass}$ (lb/h)	21,399	20,769	
<u>Beds</u>			
Amps	150	162	
$\dot{M}_{Total}$ (lb/h)	34,148	36,879	
$\dot{M}_{Fluidizing}$ (lb/h)	12,749	16,110	
T_{Plenum} ($^{\circ}R$)	573	573	
P_{Plenum} (lb/in ² a)	16.5	16.5	
ρ_{Plenum} (lb/ft ³)	0.0777	0.0775	
V_{Plenum} (ft/s)	4.70	5.97	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0693	0.0691	
V_{Top} (ft/s)	5.28	6.70	
Display (start/end)	1200/1016	1060/1292	
Bed Wt. (start/end) (lb)	2153/1506	1392/2320	
Bed Ht. (start/end) (in.)	23/16	20/26.25	
ρ_{Bed} (start/end) (lb/ft ³)	116/117	99/119	
ϕ_{Op} (s)		1200	
<u>Spargers</u>			
T_{Tank} ($^{\circ}R$)		535	
P_{Tank} (start/end) (lb/in ² g)		98/71	
ΔP_{Tank} (lb/in ²)		27	
$\Delta \dot{M}_{Total Air}$ (lb)		29.67	
Air Rate (lb/min)		1.48	
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ ($^{\circ}R$)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)		1.48	
$P_{Sparger}$ (lb/in ² g)		7.0	
Timer (on/off) (s)		1.25/12.0	
Volume (Air) (sft ³ /min)		19.81	
Material Rate ⁺ (lb/h)		17,200	
Transport Ratio (air) (lb/sft ³)		14.47	

Data Set: F5R₁

	Gasifier	Regenerator	
<u>Bypass</u>			
ΔP_0 (in. H ₂ O)	78.47	73.46	
P_1 (lb/in ² a)	16.2	16.3	
T_1 (°R)	580	575	<u>Note</u>
$P_{Fan Exit}$ (lb/in ² a)	17.3	17.3	†Sample average
$T_{Fan Exit}$ (°R)	585	574	
μ (cp)	0.01924	0.01911	
γ	0.96092	0.96368	
$\dot{Q}_{Bypass}$ (lb/s)	5.924	5.792	
$\dot{M}_{Bypass}$ (lb/h)	21,327	20,849	
<u>Beds</u>			
Amps	155	162	
$\dot{M}_{Total}$ (lb/h)	35,882	37,503	
$\dot{M}_{Fluidizing}$ (lb/h)	14,555	16,654	
T_{Plenum} (°R)	579	578	
P_{Plenum} (lb/in ² a)	16.6	16.6	
ρ_{Plenum} (lb/ft ³)	0.0775	0.0776	
V_{Plenum} (ft/s)	5.39	6.16	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0686	0.0687	
V_{Top} (ft/s)	6.09	6.96	
Display (start/end)	1084/905	1222/1251	
Bed Wt. (start/end) (lb)	1689/1289	2241/2337	
Bed Ht. (start/end) (in.)	19/14	23/27	
ρ_{Bed} (start/end) (lb/ft ³)	110/114	121/108	
ϕ_{Op} (s)		1200	
<u>Spargers</u>			
T_{Tank} (°R)		540	
P_{Tank} (start/end) (lb/in ² g)		94/79	
ΔP_{Tank} (lb/in ²)		15	
$\Delta \dot{M}_{Total Air}$ (lb)		16.33	
Air Rate (lb/min)		0.82	
$\Delta P_{Annubar}$ (in. H ₂ O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)		0.82	
$P_{Sparger}$ (lb/in ² g)		7.0	
Timer (on/off) (s)		1.25/12.0	
Volume (Air) (scf ³ /min)		10.90	
Material Rate ⁺ (lb/h)		11,760	
Transport Ratio (air)(lb/scf ³)		17.98	

Data Set: F5R₂

	Gasifier	Regenerator	
<u>Bypass</u>			
ΔP_o (in. H ₂ O)	78.18	73.75	
P_1 (lb/in ² a)	16.3	16.3	
T_1 (°R)	574	568	<u>Note</u>
$P_{Fan Exit}$ (lb/in ² a)	17.3	17.3	+Sample average
$T_{Fan Exit}$ (°R)	580	567	
μ (cp)	0.01908	0.01893	
γ	0.96140	0.96349	
$\dot{W}_{Bypass}$ (lb/s)	5.965	5.837	
$\dot{M}_{Bypass}$ (lb/h)	21.475	21.014	
<u>Beds</u>			
Amps	150	162	
$\dot{M}_{Total}$ (lb/h)	34,148	36,879	
$\dot{M}_{Fluidizing}$ (lb/h)	12,673	13,865	
T_{Plenum} (°R)	572	572	
P_{Plenum} (lb/in ² a)	16.6	16.6	
ρ_{Plenum} (lb/ft ³)	0.0784	0.0784	
V_{Plenum} (ft/s)	4.64	5.81	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0694	0.0694	
V_{Top} (ft/s)	5.24	6.56	
Display (start/end)	1152/1208	1252/1213	
Bed Wt. (start/end) (lb)	1961/2185	2361/2205	
Bed Wt. (start/end) (in.)	21/23	24/24.5	
ρ_{Bed} (start/end) (lb/ft ³)	116/118	122/112	
ϕ_{Op} (s)		1200	
<u>Spargers</u>			
T_{Tank} (°R)		535	
P_{Tank} (start/end) (lb/in ² g)		94/63	
ΔP_{Tank} (lb/in ²)		31	
$\Delta \dot{M}_{Total Air}$ (lb)		34.06	
Air Rate (lb/min)		1.70	
$\Delta P_{Annubar}$ (in. H ₂ O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)		1.70	
$P_{Sparger}$ (lb/in ² g)		9.0	
Timer (on/off) (s)		1.25/12.0	
Volume (Air) (sft ³ /min)		22.74	
Material Rate (lb/h)		7240	
Transport Ratio (air) (lb/sft ³)		5.31	

Data Set: F5R₃

	<u>Gasifier</u>	<u>Regenerator</u>	
<u>Bypass</u>	ΔP_0 (in. H ₂ O)	78.77	72.87
	P_1 (lb/in ² a)	16.3	16.1
	T_1 (°R)	580	575
	$P_{Fan Exit}$ (lb/in ² a)	17.3	17.3
	$T_{Fan Exit}$ (°R)	580	572
	μ (cp)	0.01924	0.01911
	γ	0.96113	0.96364
	$\dot{Q}_{Bypass}$ (lb/s)	5.935	5.733
	$\dot{M}_{Bypass}$ (lb/h)	21,438	20,637
<u>Beds</u>	Amps	130	160
	$\dot{M}_{Total}$ (lb/h)	33,912	36,172
	$\dot{M}_{Fluidizing}$ (lb/h)	12,474	15,535
	T_{Plenum} (°R)	570	572
	P_{Plenum} (lb/in ² a)	16.7	16.7
	ρ_{Plenum} (lb/ft ³)	0.0789	0.0786
	V_{Plenum} (ft/s)	4.52	5.65
	P_{Top} (lb/in ² a)	14.7	14.7
	ρ_{Top} (lb/ft ³)	0.0697	0.0694
	V_{Top} (ft/s)	3.14	6.42
	Display (start/end)	1240/1152	1166/1252
	Bed Wt. (start/end) (lb)	2313/1961	2017/2361
	Bed Ht. (start/end) (in.)	25/21	23/24
	ρ_{Bed} (start/end) (lb/ft ³)	115/116	109/122
	θ_{Op} (s)		900
<u>Spargers</u>	T_{Tank} (°R)		535
	P_{Tank} (start/end) (lb/in ² g)		92.5/69
	ΔP_{Tank} (lb/in ²)		23.5
	$\dot{M}_{Total Air}$ (lb)		25.82
	Air Rate (lb/min)		1.72
	$\Delta P_{Annubar}$ (in. H ₂ O)		
	$T_{Annubar}$ (°R)		
	$P_{Annubar}$ (lb/in ² a)		
	$\rho_{Bleed Air}$ (lb/ft ³)		
	$\dot{M}_{Bleed Air}$ (lb/min)		1.72
	$\dot{M}_{Pulse Air}$ (lb/min)		
	$P_{Sparger}$ (lb/in ² g)		8.5
	Timer (on/off) (s)		1.25/12.0
	Volume (Air) (sft ³ /min)		22.99
	Material Rate ⁺ (lb/h)		8360
	Transport Ratio (air)(lb/sft ³)		6.06

Note

+Sample average

Data Set: F5R₄

	Casifier	Regenerator	
<u>Bypass</u>			
ΔP_0 (in. H ₂ O)	79.95	74.05	
P_1 (lb/in ² a)	16.3	16.2	
T_1 (°R)	570	566	Note
$P_{\text{Fan Exit}}$ (lb/in ² a)	17.4	17.3	*Sample average
$T_{\text{Fan Exit}}$ (°R)	575	565	
μ (cp)	0.01898	0.01888	
γ	0.96050	0.96317	
$\dot{Q}_{\text{Bypass}}$ (lb/s)	6.048	5.839	
$\dot{Q}_{\text{Bypass}}$ (lb/h)	21,771	21,022	
<u>Beds</u>			
Amps	135	160	
$\dot{M}_{\text{Total}}$ (lb/h)	35,646	36,796	
$\dot{M}_{\text{Fluidizing}}$ (lb/h)	13,875	15,774	
T_{Plenum} (°R)	570	569	
P_{Plenum} (lb/in ² a)	16.4	16.4	
ρ_{Plenum} (lb/ft ³)	0.0778	0.0780	
V_{Plenum} (ft/s)	5.12	5.82	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0697	0.0698	
V_{Top} (ft/s)	5.72	6.49	
Display (start/end)	1175	1176	
Bed Wt. (start/end) (lb)	2053	2057	
Bed Ht. (start/end) (in.)	24	23	
ρ_{Bed} (start/end) (lb/ft ³)	106	111	
Θ_{Op} (s)			
<u>Spargers</u>			
T_{Tank} (°R)			
P_{Tank} (start/end) (lb/in ² g)			
ΔP_{Tank} (lb/in ²)			
$\Delta \dot{M}_{\text{Total Air}}$ (lb)			
Air Rate (lb/min)			
$\Delta P_{\text{Annubar}}$ (in. H ₂ O)			
T_{Annubar} (°R)			
P_{Annubar} (lb/in ² a)			
$\rho_{\text{Bleed Air}}$ (lb/ft ³)			
$\dot{M}_{\text{Bleed Air}}$ (lb/min)			
$\dot{M}_{\text{Pulse Air}}$ (lb/min)			
P_{Sparger} (lb/in ² g)		8.0	
Timer (on/off) (s)		1.25/12.0	
Volume (Air) (sft ³ /min)			
Material Rate ⁺ (lb/h)		12,040	
Transport Ratio (air) (lb/sft ³)			

Data Set: F5R₅

	Gasifier	Regenerator	
<u>Bypass</u> ΔP_o (in. H ₂ O)	80.54	74.93	
P_1 (lb/in ² a)	16.3	16.2	
T_1 (°R)	568	563	<u>Note</u>
$P_{Fan Exit}$ (lb/in ² a)	17.4	17.3	†Sample average
$T_{Fan Exit}$ (°R)	572	562	
μ (cp)	0.01893	0.01880	
γ	0.96026	0.96276	
$\dot{M}_{Bypass}$ (lb/s)	6.079	5.887	
$\dot{M}_{Bypass}$ (lb/h)	21,884	21,993	
<u>Beds</u> Amps	155	162	
$\dot{M}_{Total}$ (lb/h)	35,882	37,503	
$\dot{M}_{Fluidizing}$ (lb/h)	13,998	15,510	
T_{Plenum} (°R)	365	364	
P_{Plenum} (lb/in ² a)	16.6	16.6	
ρ_{Plenum} (lb/ft ³)	0.0791	0.0793	
V_{Plenum} (ft/s)	5.06	5.60	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0703	0.0704	
V_{Top} (ft/s)	5.72	6.32	
Display (start/end)	1178/1173	1177/1195	
Bed Wt. (start/end) (lb)	2065/2045	2061/2133	
Bed Ht. (start/end) (in.)	24/22	23/22	
ρ_{Bed} (start/end) (lb/ft ³)	107/115	111/120	
G_{Op} (s)		900	
<u>Spargers</u> T_{Tank} (°R)		535	
P_{Tank} (start/end) (lb/in ² g)		86/64	
ΔP_{Tank} (lb/in ²)		22	
$\Delta \dot{M}_{Total Air}$ (lb)		24.17	
Air Rate (lb/min)		1.61	
$\Delta P_{Annubar}$ (in. H ₂ O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)		1.61	
$P_{Sparger}$ (lb/in ² g)		8.0	
Timer (on/off) (s)		1.25/12.0	
Volume (Air) (sft ³ /min)		21.52	
Material Rate [†] (lb/h)		10,530	
Transport Ratio (air) (lb/sft ³)		8.16	

Data Set: F5R₆

	Casifier	Regenerator	
<u>Bypass</u>	79.06	74.05	
ΔP_0 (in. H ₂ O)			
P_1 (lb/in ² a)	16.3	16.2	
T_1 (°R)	585*	574*	Notes
$P_{Fan Exit}$ (lb/in ² a)	17.3	17.3	*Assumed
$T_{Fan Exit}$ (°R)	585	574	†Sample average
μ (cp)	0.01937	0.01908	
γ	0.96094	0.96315	
$\dot{Q}_{Bypass}$ (lb/s)	5.940	5.799	
$\dot{M}_{Bypass}$ (lb/h)	21,382	20,875	
<u>Beds</u>			
Amps	150	162	
$\dot{M}_{Total}$ (lb/h)	34,148	36,879	
$\dot{M}_{Fluidizing}$ (lb/h)	12,766	16,004	
T_{Plenum} (°R)	578	578	
P_{Plenum} (lb/in ² a)	16.7	16.7	
ρ_{Plenum} (lb/ft ³)	0.0779	0.0779	
V_{Plenum} (ft/s)	4.69	5.89	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0687	0.0687	
V_{Top} (ft/s)	5.33	6.69	
Display (start/end)	1236/879	1236/1319	
Bed Wt. (start/end) (lb)	2297/1238	2297/2628	
Bed Ht. (start/end) (in.)	24/14	25/32	
ρ_{Bed} (start/end) (lb/ft ³)	119/110	114/102	
ϕ_{Op} (s)		960	
<u>Spargers</u>			
T_{Tank} (°R)		542	
P_{Tank} (start/end) (lb/in ² g)		98.5/91	
ΔP_{Tank} (lb/in ²)		7.5	
$\Delta \dot{M}_{Total Air}$ (lb)		8.13	
Air Rate (lb/min)		0.51	
$\Delta P_{Annubar}$ (in. H ₂ O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)		0.51	
$P_{Sparger}$ (lb/in ² g)		7.0	
Timer (on/off) (s)		1.25/12.0	
Volume (Air) (sft ³ /min)		6.79	
Material Rate [†] (lb/h)		12,540	
Transport Ratio (air) (lb/sft ³)		30.79	

Data Set: F5R7

	<u>Gasifier</u>	<u>Regenerator</u>	
<u>Bypass</u>			
ΔP_o (in. H_2O)	79.06	73.16	
P_1 (lb/in ² a)	16.3	16.1	
T_1 (°R)	578	575	<u>Note</u>
$P_{Fan Exit}$ (lb/in ² a)	17.3	17.3	†Sample average
$T_{Fan Exit}$ (°R)	583	574	
μ (cp)	0.01919	0.01911	
γ	0.96091	0.96354	
$\dot{M}_{Bypass}$ (lb/s)	5.975	5.743	
$\dot{M}_{Bypass}$ (lb/h)	21,310	20,676	
<u>Beds</u>			
Amps	150	150	
$\dot{M}_{Total}$ (lb/h)	32,684	32,684	
$\dot{M}_{Fluidizing}$ (lb/h)	11,174	12,008	
T_{Plenum} (°R)	576	575	
P_{Plenum} (lb/in ² a)	16.3	16.3	
ρ_{Plenum} (lb/ft ³)	0.0763	0.0764	
V_{Plenum} (ft/s)	4.20	4.31	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0689	0.0690	
V_{Top} (ft/s)	4.63	4.99	
Display (start/end)	1213/1083	1083/1188	
Bed Wt. (start/end) (lb)	2203/1685	1685/2103	
Bed Ht. (start/end) (in.)	21/18	19/24.25	
ρ_{Bed} (start/end) (lb/ft ³)	130/116	110/108	
$\odot_{Op}$ (s)	1200		
<u>Spargers</u>			
T_{Tank} (°R)	539		
P_{Tank} (start/end) (lb/in ² g)	95/31		
ΔP_{Tank} (lb/in ²)	44		
$\Delta \dot{M}_{Total Air}$ (lb)	47.98		
Air Rate (lb/min)	2.40		
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)	2.40		
$P_{Sparger}$ (lb/in ² g)			
Timer (on/off) (s)	1.25/12.0		
Volume (Air) (scf/min)	32.04		
Material Rate (lb/h)	13,080		
Transport Ratio (air) (lb/scf ³)	6.80		

Data Set: F5R₈

	Casifier	Regenerator	
<u>Bypass</u>			
ΔP_o (in. H ₂ O)	77.88	72.28	
P_1 (lb/in ² a)	16.3	16.1	
T_1 (°R)	582	578	<u>Note</u>
$P_{Fan Exit}$ (lb/in ² a)	17.3	17.3	†Sample average
$T_{Fan Exit}$ (°R)	590	578	
μ (cp)	0.01929	0.01919	
γ	0.96144	0.96396	
$\dot{Q}_{Bypass}$ (lb/s)	5.913	5.697	
$\dot{M}_{Bypass}$ (lb/h)	21,288	20,508	
<u>Beds</u>			
Amps	130	160	
$\dot{M}_{Total}$ (lb/h)	33,912	36,172	
$\dot{M}_{Fluidizing}$ (lb/h)	12,624	13,664	
T_{Plenum} (°R)	588	580	
P_{Plenum} (lb/in ² a)	16.3	16.3	
ρ_{Plenum} (lb/ft ³)	0.0757	0.0767	
V_{Plenum} (ft/s)	4.79	5.86	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0675	0.0684	
V_{Top} (ft/s)	5.37	6.37	
Display (start/end)	1230/1093	1026/1233	
Bed Wt. (start/end) (lb)	2273/1725	1525/2285	
Bed Ht. (start/end) (in.)	27/19	18.5/24	
ρ_{Bed} (start/end) (lb/ft ³)	104/113	102/118	
ϕ_{Op} (s)	1200		
<u>Spargers</u>			
T_{Tank} (°R)	535		
P_{Tank} (start/end) (lb/in ² g)	961		
ΔP_{Tank} (lb/in ²)			
$\Delta \dot{M}_{Total Air}$ (lb)			
Air Rate (lb/min)			
$\Delta P_{Annubar}$ (in. H ₂ O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)			
$P_{Sparger}$ (lb/in ² g)	7.0		
Timer (on/off) (s)	1.25/12.0		
Volume (Air) (sft ³ /min)			
Material Rate (lb/h)	12,240		
Transport Ratio (air) (lb/sft ³)			

Data Set: F6

	Gasifier	Regenerator	
<u>Bypass</u>			
ΔP_o (in. H_2O)	80.24	74.93	
ρ_1 (lb/in ² a)	16.3	16.2	
T_1 (°R)	568	563	<u>Note</u>
$P_{Fan Exit}$ (lb/in ² a)	17.4	17.3	†Sample average
$T_{Fan Exit}$ (°R)	572	562	
μ (cp)	0.01893	0.01880	
γ	0.96040	0.96276	
$\dot{Q}_{Bypass}$ (lb/s)	6.068	5.887	
$\dot{Q}_{Bypass}$ (lb/h)	21,846	21,193	
<u>Beds</u>			
Amps	155	162	
$\dot{N}_{Total}$ (lb/h)	35,882	37,503	
$\dot{N}_{Fluidizing}$ (lb/h)	14,036	16,309	
T_{Plenum} (°R)	566	565	
P_{Plenum} (lb/in ² a)	16.6	16.6	
ρ_{Plenum} (lb/ft ³)	0.0790	0.0791	
V_{Plenum} (ft/s)	5.09	5.90	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0702	0.0703	
V_{Top} (ft/s)	5.74	6.66	
Display (start/end)	1179/1150	1198/1216	
Bed Wt. (start/end) (lb)	2069/1933	2145/2217	
Bed Ht. (start/end) (in.)	21/22	22/22	
ρ_{Bed} (start/end) (lb/ft ³)	122/110	121/125	
G_{Op} (s)		900	
<u>Spargers</u>			
T_{Tank} (°R)		535	
P_{Tank} (start/end) (lb/in ² g)		95/75	
ΔP_{Tank} (lb/in ²)		20	
$\Delta \dot{N}_{Total Air}$ (lb)		21.97	
Air Rate (lb/min)		1.46	
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{N}_{Bleed Air}$ (lb/min)			
$\dot{N}_{Pulse Air}$ (lb/min)		1.46	
$P_{Sparger}$ (lb/in ² g)		7.5	
Timer (on/off)(s)		1.25/14.05	
Volume (Air) (ft ³ /min)		19.56	
Material Rate [†] (lb/h)		7720	
Transport Ratio (air)(lb/ft ³)		6.58	

Data Set: F6R₁

	<u>Casifier</u>	<u>Regenerator</u>	
<u>Bypass</u>	ΔP_O (in. H ₂ O)	79.65	73.46
	P_1 (lb/in ² a)	16.3	16.2
	T_1 (°R)	575	573
	$P_{Fan Exit}$ (lb/in ² a)	17.3	17.3
	$T_{Fan Exit}$ (°R)	580	570
	μ (cp)	0.01911	0.01906
	γ	0.96064	0.96342
	$\dot{Q}_{Bypass}$ (lb/s)	6.011	5.782
	$\dot{M}_{Bypass}$ (lb/h)	21,639	20,816
<u>Beds</u>	Amps	155	160
	$\dot{M}_{Total}$ (lb/h)	35,646	36,796
	$\dot{M}_{Fluidizing}$ (lb/h)	14,007	15,980
	T_{Plenum} (°R)	573	573
	P_{Plenum} (lb/in ² a)	16.6	16.6
	ρ_{Plenum} (lb/ft ³)	0.0781	0.0781
	V_{Plenum} (ft/s)	5.14	5.86
	P_{Top} (lb/in ² a)	14.7	14.7
	ρ_{Top} (lb/ft ³)	0.0693	0.0693
	V_{Top} (ft/s)	5.80	6.62
	Display (start/end)	1132	1213
	Bed Wt. (start/end) (lb)	1881	2205
	Bed Ht. (start/end) (in.)	21/21	23/21
	ρ_{Bed} (start/end) (lb/ft ³)	111	119
	θ_{Op} (s)		900
<u>Spargers</u>	T_{Tank} (°R)		538
	P_{Tank} (start/end) (lb/in ² g)		96/80.5
	ΔP_{Tank} (lb/in ²)		15.5
	$\Delta \dot{M}_{Total Air}$ (lb)		16.94
	Air Rate (lb/min)		1.13
	$\Delta P_{Annubar}$ (in. H ₂ O)		
	$T_{Annubar}$ (°R)		
	$P_{Annubar}$ (lb/in ² a)		
	$\rho_{Bleed Air}$ (lb/ft ³)		
	$\dot{M}_{Bleed Air}$ (lb/min)		
	$\dot{M}_{Pulse Air}$ (lb/min)		1.13
	$P_{Sparger}$ (lb/in ² g)		8.0
	Timer (on/off) (s)		1.25/14.05
	Volume (Air) (sft ³ /min)		15.08
	Material Rate ⁺ (lb/h)		5940
	Transport Ratio (air) (lb/sft ³)		6.57

Note

+Sample average

Data Set: F6R₂

	Gasifier	Regenerator	
<u>Bypass</u>			
ΔP_o (in. H ₂ O)	80.24	74.34	
P_1 (lb/in ² a)	16.3	16.2	
T_1 (°R)	570	565	<u>Note</u>
$P_{Fan Exit}$ (lb/in ² a)	17.4	17.3	+sample average
$T_{Fan Exit}$ (°R)	574	564	
μ (cp)	0.01898	0.01885	
γ	0.96040	0.96305	
$\dot{M}_{Bypass}$ (lb/s)	6.058	5.855	
$\dot{M}_{Bypass}$ (lb/h)	21.808	21.079	
<u>Beds</u>			
Amps	157	162	
$\dot{M}_{Total}$ (lb/h)	36,581	37,746	
$\dot{M}_{Fluidizing}$ (lb/h)	14,773	16,668	
T_{Plenum} (°R)	569	568	
P_{Plenum} (lb/in ² a)	16.6	16.6	
ρ_{Plenum} (lb/ft ³)	0.0786	0.0787	
V_{Plenum} (ft/s)	5.38	6.06	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0698	0.0699	
V_{Top} (ft/s)	6.08	6.84	
Display (start/end)	1189/1202	1151/1200	
Bed Wt. (start/end) (lb)	2109/2161	1957/2153	
Bed Ht. (start/end) (in.)	22/21	22/22	
ρ_{Bed} (start/end) (lb/ft ³)	119/128	110/121	
G_{Op} (s)		900	
<u>Spargers</u>			
T_{Tank} (°R)		540	
P_{Tank} (start/end) (lb/in ² g)		95/80	
ΔP_{Tank} (lb/in ²)		15	
$\dot{M}_{Total Air}$ (lb)		16.33	
Air Rate (lb/min)		1.09	
$\Delta P_{Annubar}$ (in. H ₂ O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)		1.09	
$P_{Sparger}$ (lb/in ² g)		8.0	
Timer (on/off) (s)		1.25/14.05	
Volume (Air) (scf ³ /min)		14.54	
Material Rate ⁺ (lb/h)		6696	
Transport Ratio (air)(lb/scf ³)		7.68	

Data Set: F7

	Gasifier	Regenerator	
<u>Bypass</u>			
ΔP_o (in. H_2O)	79.06	73.75	
P_1 (lb/in ² a)	16.3	17.4	
T_1 (°R)	574	570	Note
$P_{Fan Exit}$ (lb/in ² a)	17.4	17.3	+Sample average
$T_{Fan Exit}$ (°R)	578	568	
μ (cp)	0.01908	0.01898	
γ	0.96094	0.96582	
$\dot{Q}_{Bypass}$ (lb/s)	3.996	6.034	
$\dot{M}_{Bypass}$ (lb/h)	21,585	21,724	
<u>Beds</u>			
Amps	135	162	
$\dot{M}_{Total}$ (lb/h)	35,882	37,503	
$\dot{M}_{Fluidizing}$ (lb/h)	14,297	15,779	
T_{Plenum} (°R)	(572)	(572)	
P_{Plenum} (lb/in ² a)	16.5	16.5	
ρ_{Plenum} (lb/ft ³)	0.0781	0.0781	
V_{Plenum} (ft/s)	5.27	5.81	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0694	0.0694	
V_{Top} (ft/s)	5.91	6.32	
Display (start/end)	1203	1168	
Bed Wt. (start/end) (lb)	2165	2025	
Bed Ht. (start/end) (in.)	21/22	21/22	
ρ_{Bed} (start/end) (lb/ft ³)	128	120	
θ_{Op} (s)		900	
<u>Spargers</u>			
T_{Tank} (°R)		540	
P_{Tank} (start/end) (lb/in ² g)		94/81	
ΔP_{Tank} (lb/in ²)		13	
$\Delta \dot{M}_{Total Air}$ (lb)		14.15	
Air Rate (lb/min)		0.94	
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)		0.94	
$P_{Sparger}$ (lb/in ² g)		8.0	
Timer (on/off) (s)		1.25/16.15	
Volume (Air) (scf ³ /min)		12.60	
Material Rate ⁺ (lb/h)		~120	
Transport Ratio (air) (lb/scf ³)		5.45	

Data Set: F7R₁

	Gasifier	Regenerator	
<u>Bypass</u>			
ΔP_0 (in. H ₂ O)	81.72	75.82	
P_1 (lb/in ² a)	16.3	16.2	
T_1 (°R)	367	362	<u>Note</u>
$P_{Fan Exit}$ (lb/in ² a)	17.4	17.4	†Sample average
$T_{Fan Exit}$ (°R)	372	361	
μ (cp)	0.01890	0.01877	
γ	0.95973	0.96237	
$\dot{Q}_{Bypass}$ (lb/s)	6.123	3.924	
$\dot{M}_{Bypass}$ (lb/h)	22,030	21,328	
<u>Beds</u>			
Amps	153	163	
$\dot{M}_{Total}$ (lb/h)	36,231	38,568	
$\dot{M}_{Fluidizing}$ (lb/h)	16,318	17,240	
T_{Plenum} (°R)	364	364	
P_{Plenum} (lb/in ² a)	16.5	16.5	
ρ_{Plenum} (lb/ft ³)	0.0791	0.0791	
V_{Plenum} (ft/s)	6.00	6.26	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0704	0.0704	
V_{Top} (ft/s)	6.73	7.03	
Display (start/end)	1197	1197	
Bed Wt. (start/end) (lb)	2141	2141	
Bed Ht. (start/end) (in.)	21	22	
ρ_{Bed} (start/end) (lb/ft ³)	126	121	
Θ_{Op} (s)		900	
<u>Spargers</u>			
T_{Tank} (°R)			
P_{Tank} (start/end) (lb/in ² g)		98.5	
ΔP_{Tank} (lb/in ²)			
$\Delta \dot{M}_{Total Air}$ (lb)			
Air Rate (lb/min)			
$\Delta P_{Annubar}$ (in. H ₂ O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{Q}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)			
$P_{Sparger}$ (lb/in ² g)		8.0	
Timer (on/off) (s)		1.25/16.13	
Volume (Air) (sft ³ /min)			
Material Rate [†] (lb/h)		3350	
Transport Ratio (air) (lb/sft ³)			

APPENDIX F
CALCULATION SHEETS FOR THE PRIMARY GASIFIER-REGENERATOR
BED-MATERIAL TRANSFER SLOT--FOURTH GENERATION--FREQUENCY
AND DURATION TESTS WITH SPARGER BLEED AIR

Data Set: FO(A)

	<u>Bypass</u>	<u>Gasifier</u>	<u>Regenerator</u>
	ΔP_0 (in. H_2O)	81.13	75.82
	P_1 (lb/in ² a)	16.3	16.2
	T_1 (°R)	578	570 ^{Note}
	$P_{Fan Exit}$ (lb/in ² a)	17.4	17.4 ^{*Sample average}
	$T_{Fan Exit}$ (°R)	578	570
	μ (cp)	0.01919	0.01898
	Y	0.95999	0.96232
	$\dot{Q}_{Bypass}$ (lb/s)	6.047	5.883
	$\dot{Q}_{Bypass}$ (lb/h)	21,768	21,178
<u>Beds</u>	Amps	155	160
	$\dot{M}_{Total}$ (lb/h)	35,646	36,796
	$\dot{Q}_{Fluidizing}$ (lb/h)	13,878	15,618
	T_{Plenum} (°R)	572	573
	P_{Plenum} (lb/in ² a)	16.4	16.4
	ρ_{Plenum} (lb/ft ³)	0.0773	0.0772
	V_{Plenum} (ft/s)	5.14	5.80
	P_{Top} (lb/in ² a)	14.7	14.7
	ρ_{Top} (lb/ft ³)	0.0694	0.0693
	V_{Top} (ft/s)	5.74	6.47
	Display (start/end)	970/1152	1253/1622
	Bed Wt. (start/end) (lb)	1416/1961	2365/1498
	Bed Ht. (start/end) (in.)	18/23	24/19
	ρ_{Bed} (start/end) (lb/ft ³)	97/106	122/98
	ϕ_{Op} (s)		264.9
<u>Spargers</u>	T_{Tank} (°R)		541
	P_{Tank} (start/end) (lb/in ² g)		95/34
	ΔP_{Tank} (lb/in ²)		41
	$\dot{M}_{Total Air}$ (lb)		44.35
	Air Rate (lb/min)		10.09
	$\Delta P_{Annubar}$ (in. H_2O)		0.0992
	$T_{Annubar}$ (°R)		541
	$P_{Annubar}$ (lb/in ² a)		34.7
	$\rho_{Bleed Air}$ (lb/ft ³)		0.1732
	$\dot{M}_{Bleed Air}$ (lb/min)		1.46
	$\dot{M}_{Pulse Air}$ (lb/min)		8.63
	$P_{Sparger}$ (lb/in ² g)		6.5
	Timer (on/off) (s)		1.25/1.15
	Volume (Air) (ft ³ /min)		134.74
	Material Rate ⁺ (lb/h)		21,600
	Transport Ratio (air) (lb/ft ³)		2.67

Data Set: F3/4(A)

	<u>Cooler</u>	<u>Regenerator</u>	
<u>Bypass</u>	ΔP_o (in. H_2O)	83.49	76.70
	P_1 (lb/in ² a)	16.4	16.2
	T_1 (°R)	565	565
	$P_{Fan Exit}$ (lb/in ² a)	17.4	17.4
	$T_{Fan Exit}$ (°R)	570	562
	μ (cp)	0.01885	0.01885
	γ	0.95896	0.96195
	$\dot{Q}_{Bypass}$ (lb/s)	6.216	5.940
	$\dot{S}_{Bypass}$ (lb/h)	22,377	21,385
<u>Beds</u>	Amps	157	157
	$\dot{S}_{Total}$ (lb/h)	35,985	35,985
	$\dot{S}_{Fluidizing}$ (lb/h)	13,608	14,600
	T_{Plenum} (°R)	566	565
	P_{Plenum} (lb/in ² a)	16.3	16.3
	ρ_{Plenum} (lb/ft ³)	0.0779	0.0780
	V_{Plenum} (ft/s)	5.01	5.37
	P_{Top} (lb/in ² a)	14.7	14.7
	ρ_{Top} (lb/ft ³)	0.0701	0.0702
	V_{Top} (ft/s)	5.37	5.96
	Display (start/end)	1029	1161
	Bed Wt. (start/end) (lb)	1331	1997
	Bed Ht. (start/end) (in.)	18.5/21.5	22.5/19.5
	ρ_{Bed} (start/end) (lb/ft ³)	103	110
	θ_{Op} (s)	124.4	
<u>Spargers</u>	T_{Tank} (°R)	541	
	P_{Tank} (start/end) (lb/in ² g)	80/67.5	
	ΔP_{Tank} (lb/in ²)	12.5	
	$\Delta \dot{Q}_{Total Air}$ (lb)	13.38	
	Air Rate (lb/min)	6.35	
	$\Delta P_{Annubar}$ (in. H_2O)		
	$T_{Annubar}$ (°R)		
	$P_{Annubar}$ (lb/in ² a)		
	$\rho_{Bleed Air}$ (lb/ft ³)		
	$\dot{S}_{Bleed Air}$ (lb/min)		
	$\dot{S}_{Pulse Air}$ (lb/min)	6.55	
	$P_{Sparger}$ (lb/in ² g)	6.5	
	Timer (on/off)(s)	1.25/3.0	
	Volume (Air) (scf/min)	87.47	
	Material Rate ⁺ (lb/h)	19,680	
	Transport Ratio (air)(lb/scf ³)	3.75	

Note

+Sample average

Data Set: F1(A)

	Gasifier	Regenerator	
<u>Bypass</u> ΔP_o (in. H_2O)	81.13	75.52	
P_1 (lb/in ² a)	16.3	16.2	
T_1 ($^{\circ}R$)	575	570	Note
$P_{Fan Exit}$ (lb/in ² a)	17.4	17.4	†Sample average
$T_{Fan Exit}$ ($^{\circ}R$)	578	570	
μ (cp)	0.01911	0.01898	
η	0.96003	0.96251	
$\dot{Q}_{Bypass}$ (lb/s)	6.063	5.872	
$\dot{M}_{Bypass}$ (lb/h)	21,826	21,140	
<u>Beds</u> I_{Amps}	157	165	
$\dot{M}_{Total}$ (lb/h)	36,930	38,812	
$\dot{M}_{Fluidizing}$ (lb/h)	15,104	17,672	
T_{Plenum} ($^{\circ}R$)	570	570	
P_{Plenum} (lb/in ² a)	16.5	16.5	
ρ_{Plenum} (lb/ft ³)	0.0782	0.0782	
V_{Plenum} (ft/s)	5.54	6.49	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0697	0.0697	
V_{Top} (ft/s)	6.22	7.28	
Display (start/end)	1067/1142	1190/1077	
Bed Wt. (start/end) (lb)	1621/1921	2113/1661	
Bed Ht. (start/end) (in.)	20/22.5	22.25/19	
ρ_{Bed} (start/end) (lb/ft ³)	100/106	118/108	
G_{Op} (s)		98	
<u>Spargers</u> T_{Tank} ($^{\circ}R$)		540	
P_{Tank} (start/end) (lb/in ² g)		95/86	
ΔP_{Tank} (lb/in ²)		9	
$\Delta \dot{M}_{Total Air}$ (lb)		9.80	
Air Rate (lb/min)		6.00	
$\Delta P_{Annubar}$ (in. H_2O)		0.992	
$T_{Annubar}$ ($^{\circ}R$)		540	
$P_{Annubar}$ (lb/in ² a)		34.7	
$\rho_{Bleed Air}$ (lb/ft ³)		0.1735	
$\dot{M}_{Bleed Air}$ (lb/min)		1.46	
$\dot{M}_{Pulse Air}$ (lb/min)		4.54	
$P_{Sparger}$ (lb/in ² g)		6.5	
Timer (on/off)(s)		1.25/3.95	
Volume (Air) (scf ³ /min)		80.10	
Material Rate ⁺ (lb/h)		21,840	
Transport Ratio (air)(lb/scf ³)		4.54	

Data Set: FLR₁(A)

		<u>Casifier</u>	<u>Regenerator</u>	
<u>Bypass</u>	ΔP_o (in. H ₂ O)	82.31	76.70	
	P_1 (lb/in ² a)	16.4	16.2	
	T_1 (°R)	570	563	<u>Note</u>
	$P_{Fan Exit}$ (lb/in ² a)	17.4	17.4	†Sample average
	$T_{Fan Exit}$ (°R)	571	560	
	μ (cp)	0.01898	0.01885	
	γ	0.95952	0.96198	
	$\dot{Q}_{Bypass}$ (lb/s)	6.148	5.941	
	$\dot{Q}_{Bypass}$ (lb/h)	22,134	21,386	
<u>Beds</u>	Amps	157	170	
	$\dot{M}_{Total}$ (lb/h)	37,497	40,602	
	$\dot{M}_{Fluidizing}$ (lb/h)	15,363	19,216	
	T_{Plenum} (°R)	566	563	
	P_{Plenum} (lb/in ² a)	16.5	16.5	
	ρ_{Plenum} (lb/ft ³)	0.0788	0.0789	
	V_{Plenum} (ft/s)	5.60	6.99	
	P_{Top} (lb/in ² a)	14.7	14.7	
	ρ_{Top} (lb/ft ³)	0.0702	0.0703	
	V_{Top} (ft/s)	6.29	7.85	
	Display (start/end)	1076/1173	1210/1073	
	Bed Wt. (start/end) (lb)	1637/2045	2193/1645	
	Bed Ht. (start/end) (in.)	19/22.5	22.75/18.5	
	ρ_{Bed} (start/end) (lb/ft ³)	108/113	119/110	
	θ_{Op} (s)		65.2	
<u>Spargers</u>	T_{Tank} (°R)		542	
	P_{Tank} (start/end) (lb/in ² g)		73/63	
	ΔP_{Tank} (lb/in ²)		10	
	$\dot{M}_{Total Air}$ (lb)		10.85	
	Air Rate (lb/min)		9.98	
	$\Delta P_{Annubar}$ (in. H ₂ O)		0.0992	
	$T_{Annubar}$ (°R)		542	
	$P_{Annubar}$ (lb/in ² a)		34.7	
	$\rho_{Bleed Air}$ (lb/ft ³)		0.1729	
	$\dot{M}_{Bleed Air}$ (lb/min)		1.46	
	$\dot{M}_{Pulse Air}$ (lb/min)		8.52	
	$P_{Sparger}$ (lb/in ² g)		6.3	
	Timer (on/off) (s)		1.25/3.95	
	Volume (Air) (sft ³ /min)		133.27	
	Material Rate [†] (lb/h)		22,320	
	Transport Ratio (air) (lb/sft ³)		2.79	

Data Set: F2(A)

	<u>Gasifier</u>	<u>Regenerator</u>	
<u>Bypass</u> ΔP_0 (in. H_2O)	79.65	73.46	
P_1 (lb/in ² a)	16.3	16.2	
T_1 (°R)	574	574	<u>Note</u>
$P_{Fan Exit}$ (lb/in ² a)	17.4	17.3	†Sample average
$T_{Fan Exit}$ (°R)	580	572	
μ (cp)	0.01908	0.01908	
γ	0.96064	0.96344	
$\dot{Q}_{Bypass}$ (lb/s)	6.017	5.777	
$\dot{M}_{Bypass}$ (lb/h)	21,663	20,798	
<u>Beds</u> Amps	155	155	
$\dot{M}_{Total}$ (lb/h)	35,042	35,042	
$\dot{M}_{Fluidizing}$ (lb/h)	13,379	14,244	
T_{Plenum} (°R)	574	575	
P_{Plenum} (lb/in ² a)	16.4	16.4	
ρ_{Plenum} (lb/ft ³)	0.0771	0.0770	
V_{Plenum} (ft/s)	4.98	5.31	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0692	0.0691	
V_{Top} (ft/s)	5.55	5.92	
Display (start/end)	1137/1140	1136/1120	
Bed Wt. (start/end) (lb)	1901/1913	1897/1833	
Bed Ht. (start/end) (in.)	21/21	20/21	
ρ_{Bed} (start/end) (lb/ft ³)	112/113	118/108	
θ_{Op} (s)		750	
<u>Spargers</u> T_{Tank} (°R)		540	
P_{Tank} (start/end) (lb/in ² g)			
ΔP_{Tank} (lb/in ²)			
$\dot{M}_{Total Air}$ (lb)			
Air Rate (lb/min)			
$\Delta P_{Annubar}$ (in. H_2O)		0.0992	
$T_{Annubar}$ (°R)		540	
$P_{Annubar}$ (lb/in ² a)		34.7	
$\rho_{Bleed Air}$ (lb/ft ³)		0.1735	
$\dot{M}_{Bleed Air}$ (lb/min)		1.46	
$\dot{M}_{Pulse Air}$ (lb/min)			
$P_{Sparger}$ (lb/in ² g)			
Timer (on/off) (s)		1.25/5.45	
Volume (Air) (sft ³ /min)			
Material Rate [†] (lb/h)		22,230	
Transport Ratio (air) (lb/sft ³)			

Data Set: F2R₁(A)

	Gasifier	Regenerator	
<u>Bypass</u>			
ΔP_0 (in. H ₂ O)	80.83	74.93	
P_1 (lb/in ² a)	16.3	16.2	
T_1 (°R)	576	570	Note
$P_{Fan Exit}$ (lb/in ² a)	17.4	17.4	†Sample average
$T_{Fan Exit}$ (°R)	580	570	
μ (cp)	0.01914	0.01898	
γ	0.96014	0.96276	
$\dot{Q}_{Bypass}$ (lb/s)	6.047	5.851	
$\dot{M}_{Bypass}$ (lb/h)	21,769	21,063	
<u>Beds</u>			
Amps	155	165	
$\dot{Q}_{Total}$ (lb/h)	36,231	38,568	
$\dot{M}_{Fluidizing}$ (lb/h)	14,462	17,505	
T_{Plenum} (°R)	574	574	
P_{Plenum} (lb/in ² a)	16.5	16.5	
ρ_{Plenum} (lb/ft ³)	0.0775	0.0775	
V_{Plenum} (ft/s)	5.35	6.47	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0692	0.0692	
V_{Top} (ft/s)	6.00	7.26	
Display (start/end)	1141/1173	1173/1148	
Bed Wt. (start/end) (lb)	1917/2045	2045/1945	
Bed Ht. (start/end) (in.)	21.5/23	22/20	
ρ_{Bed} (start/end) (lb/ft ³)	111/110	115/121	
G_{Op} (s)		900	
<u>Spargers</u>		545	
T_{Tank} (°R)			
P_{Tank} (start/end) (lb/in ² g)			
ΔP_{Tank} (lb/in ²)			
$\dot{M}_{Total Air}$ (lb)			
Air Rate (lb/min)			
$\Delta P_{Annubar}$ (in. H ₂ O)		0.1075	
$T_{Annubar}$ (°R)		545	
$P_{Annubar}$ (lb/in ² a)		34.7	
$\rho_{Bleed Air}$ (lb/ft ³)		0.1719	
$\dot{M}_{Bleed Air}$ (lb/min)		1.51	
$\dot{M}_{Pulse Air}$ (lb/min)			
$P_{Sparger}$ (lb/in ² g)		7.0	
Timer (on/off)(s)		1.25/5.45	
Volume (Air) (sft ³ /min)			
Material Rate ⁺ (lb/h)		22,290	
Transport Ratio (air)(lb/sft ³)			

Data Set: F2R₂(A)

	Gasifier	Regenerator	
<u>Bypass</u>			
ΔP_o (in. H ₂ O)	81.13	75.52	
P_1 (lb/in ² a)	16.3	16.2	
T_1 (°R)	572	568	<u>Note</u>
$P_{Fan Exit}$ (lb/in ² a)	17.4	17.4	†Sample average
$T_{Fan Exit}$ (°R)	578	568	
μ (cp)	0.01903	0.01893	
γ	0.96002	0.96251	
$\dot{Q}_{Bypass}$ (lb/s)	6.078	5.883	
$\dot{M}_{Bypass}$ (lb/h)	21,882	21,177	
<u>Beds</u>			
Amps	160	163	
$\dot{M}_{Total}$ (lb/h)	37,985	39,172	
$\dot{M}_{Fluidizing}$ (lb/h)	16,103	17,995	
T_{Plenum} (°R)	572	572	
P_{Plenum} (lb/in ² a)	16.6	16.6	
ρ_{Plenum} (lb/ft ³)	0.0784	0.0784	
V_{Plenum} (ft/s)	5.90	6.59	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0694	0.0694	
V_{Top} (ft/s)	6.66	7.44	
Display (start/end)	1173/1177	1148/1143	
Bed Wt. (start/end) (lb)	2045/2061	1945/1925	
Bed Ht. (start/end) (in.)	23/22	20/20	
ρ_{Bed} (start/end) (lb/ft ³)	110/116	121/119	
θ_{Op} (s)		900	
<u>Spargers</u>			
T_{Tank} (°R)		542	
P_{Tank} (start/end) (lb/in ² g)		89/27	
ΔP_{Tank} (lb/in ²)		62	
$\dot{M}_{Total Air}$ (lb)		67.24	
Air Rate (lb/min)		4.48	
$\Delta P_{Annubar}$ (in. H ₂ O)		0.1158	
$T_{Annubar}$ (°R)		543	
$P_{Annubar}$ (lb/in ² a)		34.7	
$\rho_{Bleed Air}$ (lb/ft ³)		0.1725	
$\dot{M}_{Bleed Air}$ (lb/min)		1.37	
$\dot{M}_{Pulse Air}$ (lb/min)		2.91	
$P_{Sparger}$ (lb/in ² g)		7.2	
Timer (on/off)(s)		1.25/3.43	
Volume (Air) (sft ³ /min)		59.86	
Material Rate (lb/h)		23,190	
Transport Ratio (air)(lb/sft ³)		6.46	

Data Set: F3(A)

		Gasifier	Regenerator	
<u>Bypass</u>	ΔP_o (in. H_2O)	79.93	73.46	
	P_1 (lb/in ² a)	16.3	16.2	
	T_1 (°R)	573	572	<u>Note</u>
	$P_{Fan Exit}$ (lb/in ² a)	17.4	17.3	†Sample average
	$T_{Fan Exit}$ (°R)	382	372	
	μ (cp)	0.01911	0.01903	
	γ	0.96052	0.96344	
	$\dot{Q}_{Bypass}$ (lb/s)	6.021	3.787	
	$\dot{Q}_{Bypass}$ (lb/h)	21,677	20,834	
<u>Beds</u>	Amps	133	162	
	$\dot{M}_{Total}$ (lb/h)	35,882	37,503	
	$\dot{M}_{Fluidizing}$ (lb/h)	14,205	16,669	
	T_{Plenum} (°R)	573	573	
	P_{Plenum} (lb/in ² a)	16.3	16.3	
	ρ_{Plenum} (lb/ft ³)	0.0777	0.0777	
	V_{Plenum} (ft/s)	3.26	6.17	
	P_{Top} (lb/in ² a)	14.7	14.7	
	ρ_{Top} (lb/ft ³)	0.0691	0.0691	
	V_{Top} (ft/s)	3.90	6.93	
	Display (start/end)	1140/1114	1120/1130	
	Bed Wt. (start/end) (lb)	1913/1809	1833/1953	
	Bed Ht. (start/end) (in.)	21/21	21/21	
	ρ_{Bed} (start/end) (lb/ft ³)	113/107	108/115	
	θ_{Op} (s)		960	
<u>Spargers</u>	T_{Tank} (°R)		340	
	P_{Tank} (start/end) (lb/in ² g)		85/38	
	ΔP_{Tank} (lb/in ²)		47	
	$\dot{M}_{Total Air}$ (lb)		51.16	
	Air Rate (lb/min)		3.20	
	$\Delta P_{Annubar}$ (in. H_2O)		0.0992	
	$T_{Annubar}$ (°R)		342	
	$P_{Annubar}$ (lb/in ² a)		34.7	
	$\rho_{Bleed Air}$ (lb/ft ³)		0.1729	
	$\dot{Q}_{Bleed Air}$ (lb/min)		1.46	
	$\dot{Q}_{Pulse Air}$ (lb/min)		1.74	
	$P_{Sparger}$ (lb/in ² g)		7.0	
	Timer (on/off) (s)		1.25/7.55	
	Volume (Air) (sft ³ /min)		42.70	
	Material Rate ⁺ (lb/h)		19,240	
	Transport Ratio (air) (lb/sft ³)		7.51	

Data Set: F3R₁(A)

	Casifier	Regenerator	
<u>Bypass</u>			
ΔP_o (in. H ₂ O)	78.77	73.46	
P_1 (lb/in ² a)	16.3	16.2	
T_1 (°R)	584	580	<u>Note</u>
$P_{Fan Exit}$ (lb/in ² a)	17.3	17.3	+Sample average
$T_{Fan Exit}$ (°R)	588	580	
μ (cp)	0.01934	0.01924	
γ	0.96106	0.96342	
$\dot{Q}_{Bypass}$ (lb/s)	5.934	5.747	
$\dot{Q}_{Bypass}$ (lb/h)	21,364	20,691	
<u>Beds</u>			
Amps	150	160	
$\dot{H}_{Total}$ (lb/h)	33,912	36,172	
$\dot{H}_{Fluidizing}$ (lb/h)	12,348	15,481	
T_{Plenum} (°R)	582	583	
P_{Plenum} (lb/in ² a)	16.5	16.5	
ρ_{Plenum} (lb/ft ³)	0.0766	0.0765	
V_{Plenum} (ft/s)	4.70	5.81	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0682	0.0681	
V_{Top} (ft/s)	5.28	6.52	
Display (start/end)	1189/1141	1203/1173	
Bed Wt. (start/end) (lb)	2109/1917	2165/2045	
Bed Ht. (start/end) (in.)	21/21.5	21.5/22	
ρ_{Bed} (start/end) (lb/ft ³)	124/111	125/115	
ϕ_{Op} (s)		900	
<u>Spargers</u>			
T_{Tank} (°R)		545	
P_{Tank} (start/end) (lb/in ² g)		82/29	
ΔP_{Tank} (lb/in ²)		53	
$\dot{H}_{Total Air}$ (lb)		57.16	
Air Rate (lb/min)		3.81	
$\Delta P_{Annubar}$ (in. H ₂ O)		0.1158	
$T_{Annubar}$ (°R)		545	
$P_{Annubar}$ (lb/in ² a)		34.7	
$\rho_{Bleed Air}$ (lb/ft ³)		0.1719	
$\dot{Q}_{Bleed Air}$ (lb/min)		1.57	
$\dot{Q}_{Pulse Air}$ (lb/min)		2.24	
$P_{Sparger}$ (lb/in ² g)		7.0	
Timer (on/off) (s)		1.25/7.55	
Volume (Air) (scf ³ /min)		50.89	
Material Rate (lb/h)		19.320	
Transport Ratio (air) (lb/scf ³)		6.33	

Data Set: F4(A)

	<u>Bypass</u>	<u>Gasifier</u>	<u>Regenerator</u>	
	ΔP_o (in. H_2O)	79.06	73.75	
	P_1 (lb/in ² a)	16.3	16.2	
	T_1 (°R)	582	578	Note
	$P_{Fan Exit}$ (lb/in ² a)	17.3	17.3	+Sample average
	$T_{Fan Exit}$ (°R)	587	576	
	μ (cp)	0.01929	0.01919	
	$\dot{V}$	0.96091	0.96327	
	$\dot{Q}_{Bypass}$ (lb/s)	5.954	5.768	
	$\dot{Q}_{Bypass}$ (lb/h)	21,436	20,764	
<u>Beds</u>	Amps	155	160	
	$\dot{Q}_{Total}$ (lb/h)	35,646	36,796	
	$\dot{Q}_{Fluidizing}$ (lb/h)	14,210	16,032	
	T_{Plenum} (°R)	576	577	
	P_{Plenum} (lb/in ² a)	16.5	16.5	
	ρ_{Plenum} (lb/ft ³)	0.0773	0.0771	
	V_{Plenum} (ft/s)	5.27	5.96	
	P_{Top} (lb/in ² a)	14.7	14.7	
	ρ_{Top} (lb/ft ³)	0.0689	0.0688	
	V_{Top} (ft/s)	5.92	6.69	
	Display (start/end)	1193/1160	1210/1197	
	Bed Wt. (start/end) (lb)	2125/1993	2193/2141	
	Bed Ht. (start/end) (in.)	21	21.5	
	C_{Bed} (start/end) (lb/ft ³)	125	126	
	Θ_{Op} (s)		900	
<u>Spargers</u>	T_{Tank} (°R)		540	
	P_{Tank} (start/end) (lb/in ² g)		90/39	
	ΔP_{Tank} (lb/in ²)		51	
	$\dot{M}_{Total Air}$ (lb)		55.52	
	Air Rate (lb/min)		3.70	
	$\Delta P_{Annubar}$ (in. H_2O)		0.1158	
	$T_{Annubar}$ (°R)		545	
	$P_{Annubar}$ (lb/in ² a)		34.7	
	$\rho_{Bleed Air}$ (lb/ft ³)		0.1719	
	$\dot{Q}_{Bleed Air}$ (lb/min)		1.57	
	$\dot{Q}_{Pulse Air}$ (lb/min)		2.13	
	$P_{Sparger}$ (lb/in ² g)		7.0	
	Timer (on/off) (s)		1.25/9.95	
	Volume (Air) (sft ³ /min)		49.42	
	Material Rate ⁺ (lb/h)		14,160	
	Transport Ratio (air)(lb/sft ³)		4.78	

Data Set: F4R₁(A)

		Gasifier	Regenerator	
<u>Bypass</u>	ΔP_o (in. H ₂ O)	80.24	74.64	
	P_1 (lb/in ² a)	16.3	16.2	
	T_1 ("R)	372	368	<u>Note</u>
	$P_{Fan Exit}$ (lb/in ² a)			†Sample average
	$T_{Fan Exit}$ ("R)	377	367	
	μ (cp)	0.01903	0.01893	
	γ	0.96038	0.96290	
	$\dot{Q}_{Bypass}$ (lb/s)	6.047	5.851	
	$\dot{M}_{Bypass}$ (lb/h)	21,770	21,062	
<u>Beds</u>	Amps	160	162	
	$\dot{M}_{Total}$ (lb/h)	37,636	38,106	
	$\dot{M}_{Fluidizing}$ (lb/h)	15,866	17,044	
	T_{Plenum} ("R)	370	370	
	P_{Plenum} (lb/in ² a)	16.5	16.5	
	ρ_{Plenum} (lb/ft ³)	0.0781	0.0781	
	V_{Plenum} (ft/s)	5.82	6.26	
	P_{Top} (lb/in ² a)	14.7	14.7	
	ρ_{Top} (lb/ft ³)	0.0697	0.0697	
	V_{Top} (ft/s)	6.54	7.02	
	Display (start/end)	1139	1157	
	Bed Wt. (start/end) (lb)	1909	1981	
	Bed Ht. (start/end) (in.)	20	21	
	ρ_{Bed} (start/end) (lb/ft ³)			
	ϕ_{Op} (s)		900	
<u>Spargers</u>	T_{Tank} ("R)		535	
	P_{Tank} (start/end) (lb/in ² g)			
	ΔP_{Tank} (lb/in ²)			
	$\dot{M}_{Total Air}$ (lb)			
	Air Rate (lb/min)			
	$\Delta P_{Annubar}$ (in. H ₂ O)		0.1158	
	$T_{Annubar}$ ("R)		340	
	$P_{Annubar}$ (lb/in ² a)		34.7	
	$\rho_{Bleed Air}$ (lb/ft ³)		0.1735	
	$\dot{M}_{Bleed Air}$ (lb/min)		1.58	
	$\dot{M}_{Pulse Air}$ (lb/min)			
	$P_{Sparger}$ (lb/in ² g)		7.0	
	Timer (on/off) (s)		1.25/9.95	
	Volume (Air) (sft ³ /min)			
	Material Rate ⁺ (lb/h)		13,248	
	Transport Ratio (air) (lb/sft ³)			

Data Set: F4R₂ (A)

		Casifier	Regenerator	
<u>Bypass</u>	ΔP_0 (in. H ₂ O)	79.95	74.64	
	P_1 (lb/in ² a)	16.3	16.2	
	T_1 (°R)	574	570	Note
	$P_{Fan Exit}$ (lb/in ² a)	17.4	17.3	+Sample average
	$T_{Fan Exit}$ (°R)	575	566	
	μ (cp)	0.01908	0.01898	
	γ	0.96052	0.96288	
	$\dot{Q}_{Bypass}$ (lb/s)	6.027	5.840	
	$\dot{H}_{Bypass}$ (lb/h)	21,696	21,025	
<u>Beds</u>	Amps	160	160	
	$\dot{Q}_{Total}$ (lb/h)	37,400	37,400	
	$\dot{H}_{Fluidizing}$ (lb/h)	15,704	16,375	
	T_{Plenum} (°R)	568	568	
	P_{Plenum} (lb/in ² a)	16.5	16.5	
	ρ_{Plenum} (lb/ft ³)	0.0784	0.0784	
	V_{Plenum} (ft/s)	5.74	5.99	
	P_{Top} (lb/in ² a)	14.7	14.7	
	ρ_{Top} (lb/ft ³)	0.0699	0.0699	
	V_{Top} (ft/s)	6.45	6.72	
	Display (start/end)	1122/1164	1156/1130	
	Bed Wt. (start/end) (lb)	1841/2009	1977/1873	
	Bed Ht. (start/end) (in.)	21/21	21/22	
	ρ_{Bed} (start/end) (lb/ft ³)	109/119	117/106	
	θ_{Op} (s)		1380	
			540	
	<u>Spargers</u> T_{Tank} (°R)			
	P_{Tank} (start/end) (lb/in ² g)			
	ΔP_{Tank} (lb/in ²)			
	$\Delta \dot{H}_{Total Air}$ (lb)			
	Air Rate (lb/min)			
	$\Delta P_{Annubar}$ (in. H ₂ O)		0.0992	
	$T_{Annubar}$ (°R)		540	
	$P_{Annubar}$ (lb/in ² a)		34.7	
	$\rho_{Bleed Air}$ (lb/ft ³)		0.1735	
	$\dot{H}_{Bleed Air}$ (lb/min)		1.46	
	$\dot{H}_{Pulse Air}$ (lb/min)			
	$P_{Sparger}$ (lb/in ² g)		7.0	
	Timer (on/off) (s)		1.25/9.93	
	Volume (Air) (scf ³ /min)			
	Material Rate ⁺ (lb/h)			
	Transport Ratio (air) (lb/scf ³)		13,840	

Data Set: F5(A)

	<u>Gasifier</u>	<u>Regenerator</u>
<u>Bypass</u> ΔP_0 (in. H_2O)	79.93	74.93
P_1 (lb/in ² a)	16.3	16.2
T_1 (°R)	572	567 <u>Note</u>
$P_{Fan Exit}$ (lb/in ² a)	17.4	17.3 †Sample average
$T_{Fan Exit}$ (°R)	577	567
μ (cp)	0.01903	0.01890
γ	0.96032	0.96276
$\dot{Q}_{Bypass}$ (lb/s)	6.037	5.866
$\dot{N}_{Bypass}$ (lb/h)	21,734	21,118
<u>Beds</u> I_{Amps}	157	167
$\dot{N}_{Total}$ (lb/h)	37,159	39,526
$\dot{N}_{Fluidizing}$ (lb/h)	15,423	18,406
T_{Plenum} (°R)	571	570
P_{Plenum} (lb/in ² a)	16.5	16.5
ρ_{Plenum} (lb/ft ³)	0.0782	0.0783
V_{Plenum} (ft/s)	5.67	6.76
P_{Top} (lb/in ² a)	14.71	14.71
ρ_{Top} (lb/ft ³)	0.0695	0.0697
V_{Top} (ft/s)	6.37	7.58
Display (start/end)	1178/1126	1115/1146
Bed Wt. (start/end) (lb)	2065/1857	1813/1937
Bed Ht. (start/end) (in.)	22/22	20/21
ρ_{Bed} (start/end) (lb/ft ³)	116/105	112/114
Θ_{Op} (s)	1020	
<u>Spargers</u> T_{Tank} (°R)		537
P_{Tank} (start/end) (lb/in ² g)		85/42
ΔP_{Tank} (lb/in ²)		43
$\Delta \dot{M}_{Total Air}$ (lb)		47.07
Air Rate (lb/min)		2.77
$\Delta P_{Annubar}$ (in. H_2O)		0.0827
$T_{Annubar}$ (°R)		537
$P_{Annubar}$ (lb/in ² a)		35.2
$\rho_{Bleed Air}$ (lb/ft ³)		0.1770
$\dot{N}_{Bleed Air}$ (lb/min)		1.35
$\dot{N}_{Pulse Air}$ (lb/min)		1.42
$P_{Sparger}$ (lb/in ² g)		7.0
Timer (on/off)(s)		1.25/12.0
Volume (Air) (scf ³ /min)		36.97
Material Rate (lb/h)		12,480
Transport Ratio (air) (lb/scf ³)		5.63

Data Set: FSR₁ (A)

	Gasifier	Regenerator	
<u>Bypass</u>			
ΔP_0 (in. H ₂ O)	79.65	74.64	
P_1 (lb/in ² a)	16.3	16.2	
T_1 (°R)	574	568	Note
$P_{Fan Exit}$ (lb/in ² a)	17.4	17.3	†Sample average
$T_{Fan Exit}$ (°R)	577	567	
μ (cp)	0.01908	0.01893	
γ	0.96070	0.96290	
$\dot{Q}_{Bypass}$ (lb/s)	6.017	5.851	
$\dot{M}_{Bypass}$ (lb/h)	21,659	21,062	
<u>Beds</u>			
Amps	155	162	
$\dot{M}_{Total}$ (lb/h)	35,882	37,303	
$\dot{M}_{Fluidizing}$ (lb/h)	14,223	16,441	
T_{Plenum} (°R)	572	571	
P_{Plenum} (lb/in ² a)	16.5	16.5	
ρ_{Plenum} (lb/ft ³)	0.0780	0.0781	
V_{Plenum} (ft/s)	5.24	6.05	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0694	0.0696	
V_{Top} (ft/s)	5.88	6.79	
Display (start/end)	1164/1135	1130/1113	
Bed Wt. (start/end) (lb)	2009/1893	1873/1805	
Bed Wt. (start/end) (in.)	21/22	22/21	
ρ_{Bed} (start/end) (lb/ft ³)	119/107	106/107	
θ_{Op} (s)		900	
<u>Spargers</u>			
T_{Tank} (°R)		540	
P_{Tank} (start/end) (lb/in ² g)		89/53	
ΔP_{Tank} (lb/in ²)		36	
$\Delta \dot{M}_{Total Air}$ (lb)		39.19	
Air Rate (lb/min)		2.61	
$\Delta P_{Annubar}$ (in. H ₂ O)		0.0992	
$T_{Annubar}$ (°R)		542	
$P_{Annubar}$ (lb/in ² a)		34.7	
$\rho_{Bleed Air}$ (lb/ft ³)		0.1729	
$\dot{M}_{Bleed Air}$ (lb/min)		1.46	
$\dot{M}_{Pulse Air}$ (lb/min)		1.15	
$P_{Sparger}$ (lb/in ² g)		7.0	
Timer (on/off) (s)		1.25/12.0	
Volume (Air) (sft ³ /min)		34.89	
Material Rate [†] (lb/h)		12,840	
Transport Ratio (air) (lb/sft ³)		6.13	

Data Set: F6(A)

	<u>Gasifier</u>	<u>Regenerator</u>	
<u>Bypass</u>			
ΔP_0 (in. H_2O)	79.95	74.93	
P_1 (lb/in ² a)	16.3	16.2	
T_1 (°R)	572	566	<u>Note</u>
$P_{Fan Exit}$ (lb/in ² a)	17.4	17.4	†Sample average
$T_{Fan Exit}$ (°R)	575	566	
L (cp)	0.01903	0.01888	
γ	0.96053	0.96276	
$\dot{U}_{Bypass}$ (lb/s)	6.037	5.871	
$\dot{N}_{Bypass}$ (lb/h)	21,734	21,137	
<u>Beds</u>			
Amps	153	165	
$\dot{N}_{Total}$ (lb/h)	36,231	38,568	
$\dot{N}_{Fluidizing}$ (lb/h)	14,497	17,431	
T_{Plenum} (°R)	569	569	
P_{Plenum} (lb/in ² a)	16.3	16.3	
ρ_{Plenum} (lb/ft ³)	0.0783	0.0783	
V_{Plenum} (ft/s)	5.31	6.39	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0698	0.0698	
V_{Top} (ft/s)	5.96	7.17	
Display (start/end)	1170/1159	1135/1050	
Bed Wt. (start/end) (lb)	2033/1989	1893/1572	
Bed Ht. (start/end) (in.)	21/22	20.5/20.0	
ρ_{Bed} (start/end) (lb/ft ³)	120/112	114/97	
θ_{Op} (s)		1020	
<u>Spargers</u>			
T_{Tank} (°R)		543	
P_{Tank} (start/end) (lb/in ² g)		98/60	
ΔP_{Tank} (lb/in ²)		38	
$\Delta \dot{N}_{Total Air}$ (lb)		40.98	
Air Rate (lb/min)		2.41	
$\Delta P_{Annubar}$ (in. H_2O)		0.0910	
$T_{Annubar}$ (°R)		536	
$P_{Annubar}$ (lb/in ² a)		35.3	
$\rho_{Bleed Air}$ (lb/ft ³)		0.1778	
$\dot{N}_{Bleed Air}$ (lb/min)		1.41	
$\dot{N}_{Pulse Air}$ (lb/min)		1.00	
$P_{Sparger}$ (lb/in ² g)		6.3	
Timer (on/off)(s)		1.25/14.05	
Volume (Air) (sft ³ /min)		32.19	
Material Rate [†] (lb/h)		9400	
Transport Ratio (air)(lb/sft ³)		4.87	

Data Set: F6R₁(A)

	Gasifier	Regenerator	
<u>Bypass</u>			
ΔP_o (in. H ₂ O)	79.65	74.05	
P_1 (lb/in ² a)	16.3	16.2	
T_1 (*R)	584	580	<u>Note</u>
$P_{Fan Exit}$ (lb/in ² a)	17.4	17.3	†Sample average
$T_{Fan Exit}$ (*R)	582	573	
μ (cp)	0.01934	0.01924	
γ	0.96064	0.96313	
$\dot{Q}_{Bypass}$ (lb/s)	5.965	5.769	
$\dot{M}_{Bypass}$ (lb/h)	21.473	20.768	
<u>Beds</u>			
Amps	150	163	
$\dot{M}_{Total}$ (lb/h)	34,496	37,946	
$\dot{M}_{Fluidizing}$ (lb/h)	13,023	17,178	
T_{Plenum} (*R)	573	574	
P_{Plenum} (lb/in ² a)	16.5	16.3	
ρ_{Plenum} (lb/ft ³)	0.0776	0.0775	
V_{Plenum} (ft/s)	4.81	6.35	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0693	0.0692	
V_{Top} (ft/s)	5.39	7.13	
Display (start/end)	1192/1123	1117/1149	
Bed Wt. (start/end) (lb)	2121/1843	1821/1949	
Bed Ht. (start/end) (in.)	22/22	21/20	
ρ_{Bed} (start/end) (lb/ft ³)	119/104	107/121	
$\dot{Q}_{Op}$ (s)		900	
<u>Spargers</u>			
T_{Tank} (*R)		545	
P_{Tank} (start/end) (lb/in ² g)		89/55	
ΔP_{Tank} (lb/in ²)		34	
$\Delta \dot{M}_{Total Air}$ (lb)		36.67	
Air Rate (lb/min)		2.44	
$\Delta P_{Annubar}$ (in. H ₂ O)		0.1158	
$T_{Annubar}$ (*R)		545	
$P_{Annubar}$ (lb/in ² a)		34.7	
$\rho_{Bleed Air}$ (lb/ft ³)		0.1719	
$\dot{M}_{Bleed Air}$ (lb/min)		1.57	
$\dot{M}_{Pulse Air}$ (lb/min)		0.87	
$P_{Sparger}$ (lb/in ² g)		6.5	
Timer (on/off) (s)		1.25/14.05	
Volume (Air) (sft ³ /min)		32.65	
Material Rate ⁺ (lb/h)		8000	
Transport Ratio (air)(lb/sft ³)		4.08	

Data Set: F7(A)

	Gasifier	Regenerator
<u>Bypass</u> ΔP_o (in. H_2O)	80.34	74.93
P_1 (lb/in ² a)	16.3	16.2
T_1 (°R)	370	567
$P_{Fan Exit}$ (lb/in ² a)	17.4	17.3
$T_{Fan Exit}$ (°R)	371	563
μ (cp)	0.01898	0.01890
γ	0.96026	0.96276
$\dot{Q}_{Bypass}$ (lb/s)	6.068	5.866
$\dot{M}_{Bypass}$ (lb/h)	21.846	21.118
<u>Beds</u> Amps	132	162
$\dot{M}_{Total}$ (lb/h)	34,839	37,131
$\dot{M}_{Fluidizing}$ (lb/h)	12,993	16,013
T_{Plenum} (°R)	563	564
P_{Plenum} (lb/in ² a)	16.4	16.4
ρ_{Plenum} (lb/ft ³)	0.0786	0.0786
V_{Plenum} (ft/s)	4.74	5.85
P_{Top} (lb/in ² a)	14.7	14.7
ρ_{Top} (lb/ft ³)	0.0705	0.0705
V_{Top} (ft/s)	5.29	6.53
Display (start/end)	1156	1098
Bed Wt. (start/end) (lb)	1977	1743
Bed Ht. (start/end) (in.)	22	20
ρ_{Bed} (start/end) (lb/ft ³)	123	108
G_{Op} (s)		900
<u>Spargers</u> T_{Tank} (°R)		536
P_{Tank} (start/end) (lb/in ² g)		92/66.3
ΔP_{Tank} (lb/in ²)		25.3
$\Delta \dot{M}_{Total Air}$ (lb)		27.96
Air Rate (lb/min)		1.86
$\Delta P_{Annubar}$ (in. H_2O)		0.0827
$T_{Annubar}$ (°R)		537
$P_{Annubar}$ (lb/in ² a)		35.2
$\rho_{Bleed Air}$ (lb/ft ³)		0.1770
$\dot{M}_{Bleed Air}$ (lb/min)		1.33
$\dot{M}_{Pulse Air}$ (lb/min)		0.31
$P_{Sparger}$ (lb/in ² g)		6.3
Timer (on/off) (s)		1.23/16.13
Volume (Air) (sft ³ /min)		24.90
Material Rate (lb/h)		8580
Transport Ratio (air)(lb/sft ³)		5.74

Note

†Sample average

Data Set: F7R₁(A)

		Gasifier	Regenerator	
<u>Bypass</u>	ΔP_o (in. H ₂ O)	79.95	74.93	
	P_1 (lb/in ² a)	16.3	16.2	
	T_1 (°R)	573	568	<u>Note</u>
	$P_{Fan Exit}$ (lb/in ² a)	17.4	17.4	+Sample average
	$T_{Fan Exit}$ (°R)	578	567	
	μ (cp)	0.01906	0.01893	
	γ	0.96052	0.96276	
	$\dot{Q}_{Bypass}$ (lb/s)	6.032	5.861	
	$\dot{H}_{Bypass}$ (lb/h)	21,715	21,100	
<u>Beds</u>	Amps	152	163	
	$\dot{H}_{Total}$ (lb/h)	35,188	38,197	
	$\dot{H}_{Fluidizing}$ (lb/h)	13,473	17,097	
	T_{Plenum} (°R)	570	570	
	P_{Plenum} (lb/in ² a)	16.5	16.5	
	ρ_{Plenum} (lb/ft ³)	0.0779	0.0779	
	V_{Plenum} (ft/s)	4.95	6.28	
	P_{Top} (lb/in ² a)	14.7	14.7	
	ρ_{Top} (lb/ft ³)	0.0697	0.0697	
	V_{Top} (ft/s)	5.35	7.04	
	Display (start/end)	1126/1093	1146/1164	
	Bed Wt. (start/end) (lb)	1857/1725	1937/2009	
	Bed Ht. (start/end) (in.)	22/23	21/20	
	ρ_{Bed} (start/end) (lb/ft ³)	105/93	114/124	
	θ_{Op} (s)		900	
<u>Spargers</u>	T_{Tank} (°R)		537	
	P_{Tank} (start/end) (lb/in ² g)		66/37	
	ΔP_{Tank} (lb/in ²)		29	
	$\Delta \dot{H}_{Total Air}$ (lb)		31.74	
	Air Rate (lb/min)		2.12	
	$\Delta P_{Annubar}$ (in. H ₂ O)		0.09010	
	$T_{Annubar}$ (°R)		538	
	$P_{Annubar}$ (lb/in ² a)		34.7	
	$\rho_{Bleed Air}$ (lb/ft ³)		0.1741	
	$\dot{H}_{Bleed Air}$ (lb/min)		1.40	
	$\dot{H}_{Pulse Air}$ (lb/min)		0.72	
	$P_{Sparger}$ (lb/in ² g)		6.5	
	Timer (on/off) (s)		1.25/16.15	
	Volume (Air) (scf ³ /min)		28.26	
	Material Rate ⁺ (lb/h)		8430	
	Transport Ratio (air) (lb/scf ³)		4.97	

Data Set: F7R₂ (A)

	Gasifier	Regenerator	
<u>Bypass</u>			
ΔP_o (in. H ₂ O)	79.95	74.05	
P_1 (lb/in ² a)	16.3	16.2	
T_1 ("R)	578	574	<u>Note</u>
$P_{Fan Exit}$ (lb/in ² a)	17.4	17.3	†Sample average
$T_{Fan Exit}$ ("R)	583	573	
μ (cp)	0.01919	0.01908	
γ	0.96052	0.96315	
$\dot{Q}_{Bypass}$ (lb/s)	6.006	5.799	
$\dot{M}_{Bypass}$ (lb/h)	21,621	20,875	
<u>Beds</u>			
Amps	155	165	
$\dot{M}_{Total}$ (lb/h)	36,231	38,568	
$\dot{M}_{Fluidizing}$ (lb/h)	14,610	17,693	
T_{Plenum} ("R)	577	576	
P_{Plenum} (lb/in ² a)	16.6	16.6	
ρ_{Plenum} (lb/ft ³)	0.0777	0.0777	
V_{Plenum} (ft/s)	5.40	6.32	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0688	0.0690	
V_{Top} (ft/s)	6.09	7.37	
Display (start/end)	1123/1121	1149/1111	
Bed Wt. (start/end) (lb)	1845/1837	1949/1797	
Bed Ht. (start/end) (in.)	22/22	20/20	
ρ_{Bed} (start/end) (lb/ft ³)	104/103	121/111	
ϕ_{Op} (s)		900	
<u>Spargers</u>			
T_{Tank} ("R)		545	
P_{Tank} (start/end) (lb/in ² g)		94/65	
ΔP_{Tank} (lb/in ²)		29	
$\dot{M}_{Total Air}$ (lb)		31.28	
Air Rate (lb/min)		2.09	
$\Delta P_{Annubar}$ (in. H ₂ O)		0.1158	
$T_{Annubar}$ ("R)		543	
$P_{Annubar}$ (lb/in ² a)		34.7	
$\dot{Q}_{Bleed Air}$ (lb/ft ³)		0.1725	
$\dot{M}_{Bleed Air}$ (lb/min)		1.57	
$\dot{M}_{Pulse Air}$ (lb/min)		0.52	
$P_{Sparger}$ (lb/in ² g)		6.5	
Timer (on/off) (s)		1.25/16.15	
Volume (Air) (sft ³ /min)		27.84	
Material Rate (lb/h)		6520	
Transport Ratio (air) (lb/sft ³)		3.90	

Data Set: F8(A)

	Gasifier	Regenerator	
<u>Bypass</u>			
ΔP_0 (in. H_2O)	79.65	72.87	
P_1 (lb/in ² a)	16.3	16.1	
T_1 (°R)	585	580	<u>Note</u>
$P_{Fan Exit}$ (lb/in ² a)	17.3	17.3	†Sample average
$T_{Fan Exit}$ (°R)	590	580	
μ (cp)	0.01937	0.01924	
γ	0.96062	0.96369	
$\dot{M}_{Bypass}$ (lb/s)	5.960	5.708	
$\dot{M}_{Bypass}$ (lb/h)	21,455	20,550	
<u>Beds</u>			
Amps	165	155	
$\dot{M}_{Total}$ (lb/h)	38,568	36,231	
$\dot{M}_{Fluidizing}$ (lb/h)	17,113	15,681	
T_{Plenum} (°R)	583	583	
P_{Plenum} (lb/in ² a)	16.6	16.6	
ρ_{Plenum} (lb/ft ³)	0.0770	0.0770	
V_{Plenum} (ft/s)	6.39	5.85	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0681	0.0681	
V_{Top} (ft/s)	7.21	6.61	
Display (start/end)	1188	1089	
Bed Wt. (start/end) (lb)	2105	1709	
Bed Ht. (start/end) (in.)	23	20	
ρ_{Bed} (start/end) (lb/ft ³)	113	106	
G_{Op} (s)		900	
<u>Spargers</u>			
T_{Tank} (°R)		546	
P_{Tank} (start/end) (lb/in ² g)		75/48	
ΔP_{Tank} (lb/in ²)		27	
$\Delta \dot{M}_{Total Air}$ (lb)		29.07	
Air Rate (lb/min)		1.94	
$\Delta P_{Annubar}$ (in. H_2O)		0.0992	
$T_{Annubar}$ (°R)		545	
$P_{Annubar}$ (lb/in ² a)		34.7	
$\rho_{Bleed Air}$ (lb/ft ³)		0.1719	
$\dot{M}_{Bleed Air}$ (lb/min)		1.45	
$\dot{M}_{Pulse Air}$ (lb/min)		0.49	
$P_{Sparger}$ (lb/in ² g)		7	
Timer (on/off) (s)		1.25/18.20	
Volume (Air) (sft ³ /min)		25.88	
Material Rate ⁺ (lb/h)		6885	
Transport Ratio (air)(lb/sft ³)		4.43	

Data Set: F8R₁(A)

	Gasifier	Regenerator
<u>Bypass</u>		
ΔP_o (in. H ₂ O)	78.77	72.57
P_1 (lb/in ² a)	16.3	16.1
T_1 (°R)	585	582
$P_{Fan Exit}$ (lb/in ² a)	17.3	17.3
$T_{Fan Exit}$ (°R)	590	580
μ (cp)	0.01937	0.01929
γ	0.96103	0.96379
$\dot{Q}_{Bypass}$ (lb/s)	5.929	5.687
$\dot{N}_{Bypass}$ (lb/h)	21,345	20,475
<u>Beds</u>		
Amps	165	155
$\dot{N}_{Total}$ (lb/h)	38,568	36,231
$\dot{Q}_{Fluidizing}$ (lb/h)	17,223	15,756
T_{Plenum} (°R)	586	586
P_{Plenum} (lb/in ² a)	16.6	16.6
ρ_{Plenum} (lb/ft ³)	0.0765	0.0765
V_{Plenum} (ft/s)	6.46	5.91
P_{Top} (lb/in ² a)	14.7	14.7
ρ_{Top} (lb/ft ³)	0.0677	0.0677
V_{Top} (ft/s)	7.30	6.67
Display (start/end)	1209/1187	1101/1160
Bed Wt. (start/end) (lb)	2189/2101	1757/1993
Bed Ht. (start/end) (in.)	23/22	20/21
ρ_{Bed} (start/end) (lb/ft ³)	118/118	109/118
ϕ_{Op} (s)		900
<u>Spargers</u>		
T_{Tank} (°R)		546
P_{Tank} (start/end) (lb/in ² g)		97/72*
ΔP_{Tank} (lb/in ²)		25
$\dot{N}_{Total Air}$ (lb)		26.91
Air Rate (lb/min)		1.79
$\Delta P_{Annubar}$ (in. H ₂ O)		0.0901
$T_{Annubar}$ (°R)		547
$P_{Annubar}$ (lb/in ² a)		34.7
$\rho_{Bleed Air}$ (lb/ft ³)		0.1713
$\dot{N}_{Bleed Air}$ (lb/min)		1.39
$\dot{N}_{Pulse Air}$ (lb/min)		0.40
$P_{Sparger}$ (lb/in ² g)		7
Timer (on/off)(s)		1.25/18.20
Volume (Air) (scf ³ /min)		23.96
Material Rate ⁺ (lb/h)		7560
Transport Ratio (air)(lb/scf ³)		3.26

Notes

*Calculated as follows:
 (1 pulse/18.2 s) x (900 s) =
 50 pulses x (0.3 lb/in²/pulse) = 25 lb/in²
 97 - 25 = 72 lb/in²
 †Sample average

Data Set: F9(A)

	<u>Gasifier</u>	<u>Regenerator</u>	
<u>Bypass</u>			
ΔP_0 (in. H_2O)	81.72	74.05	
P_1 (lb/in ² a)	16.3	16.2	
T_1 (°R)	585	580	<u>Note</u>
$P_{Fan Exit}$ (lb/in ² a)	17.3	17.3	†Sample average
$T_{Fan Exit}$ (°R)	590	580	
μ (cp)	0.01937	0.01924	
γ	0.95960	0.96312	
$\dot{Q}_{Bypass}$ (lb/s)	6.030	5.769	
$\dot{M}_{Bypass}$ (lb/h)	21,708	20,767	
<u>Beds</u>			
Amps	155	165	
$\dot{Q}_{Total}$ (lb/h)	36,231	38,568	
$\dot{M}_{Fluidizing}$ (lb/h)	14,523	17,801	
T_{Plenum} (°R)	582	582	
P_{Plenum} (lb/in ² a)	16.5	16.5	
ρ_{Plenum} (lb/ft ³)	0.0767	0.0767	
V_{Plenum} (ft/s)	3.44	6.67	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0682	0.0682	
V_{Top} (ft/s)	6.11	7.49	
Display (start/end)	1194/1192	1170/1093	
Bed Wt. (start/end) (lb)	2129/2121	2033/1725	
Bed Ht. (start/end) (in.)	22/24	21/20	
ρ_{Bed} (start/end) (lb/ft ³)	120/110	120/107	
$\dot{Q}_{Op}$ (s)		960	
<u>Spargers</u>			
T_{Tank} (°R)		546	
P_{Tank} (start/end) (lb/in ² g)		94/64	
ΔP_{Tank} (lb/in ²)		30	
$\dot{M}_{Total Air}$ (lb)		32.30	
Air Rate (lb/min)		2.02	
$\Delta P_{Annubar}$ (in. H_2O)		0.0992	
$T_{Annubar}$ (°R)		546	
$P_{Annubar}$ (lb/in ² a)		34.7	
$\rho_{Bleed Air}$ (lb/ft ³)		0.1716	
$\dot{M}_{Bleed Air}$ (lb/min)		1.45	
$\dot{M}_{Pulse Air}$ (lb/min)		0.57	
$P_{Sparger}$ (lb/in ² g)		7.0	
Timer (on/off) (s)		1.25/20.05	
Volume (Air) (scf ³ /min)		26.96	
Material Rate (lb/h)		6480	
Transport Ratio (air) (lb/scf ³)		4.01	

Data Set: F9R₁(A)

	<u>Casifier</u>	<u>Regenerator</u>	
<u>Bypass</u>			
ΔP_o (in. H ₂ O)	78.77	74.05	
P_1 (lb/in ² a)	16.3	16.2	
T_1 (°R)	585	580	<u>Note</u>
$P_{Fan Exit}$ (lb/in ² a)	17.3	17.3	+Sample average
$T_{Fan Exit}$ (°R)	585	580	
μ (cp)	0.01937	0.01924	
η	0.96108	0.96315	
$\dot{Q}_{Bypass}$ (lb/s)	5.929	5.769	
$\dot{H}_{Bypass}$ (lb/h)	21,346	20,768	
<u>Beds</u>			
Amps	150	162	
$\dot{Q}_{Total}$ (lb/h)	34,148	36,879	
$\dot{H}_{Fluidising}$ (lb/h)	12,802	16,111	
T_{Plenum} (°R)	580	580	
P_{Plenum} (lb/in ² a)	16.5	16.5	
ρ_{Plenum} (lb/ft ³)	0.0766	0.0766	
V_{Plenum} (ft/s)	4.78	6.02	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0684	0.0684	
V_{Top} (ft/s)	5.37	6.75	
Display (start/end)	1192/1176	1093/1143	
Bed Wt. (start/end) (lb)	2121/2057	1725/1925	
Bed Ht. (start/end) (in.)	24/22	20/21	
ρ_{Bed} (start/end) (lb/ft ³)	110/116	107/114	
ϕ_{Op} (s)		900	
<u>Spargers</u>			
T_{Tank} (°R)		546	
P_{Tank} (start/end) (lb/in ² g)		90/63	
ΔP_{Tank} (lb/in ²)		27	
$\Delta \dot{M}_{Total Air}$ (lb)		29.07	
Air Rate (lb/min)		1.94	
$\Delta P_{Annubar}$ (in. H ₂ O)		0.0901	
$T_{Annubar}$ (°R)		544	
$P_{Annubar}$ (lb/in ² a)		34.7	
$\rho_{Bleed Air}$ (lb/ft ³)		0.1722	
$\dot{H}_{Bleed Air}$ (lb/min)		1.39	
$\dot{H}_{Pulse Air}$ (lb/min)		0.55	
$P_{Sparger}$ (lb/in ² g)		6.75	
Timer (on/off)(s)		1.25/20.05	
Volume (Air) (scf ³ /min)		25.88	
Material Rate (lb/h)		6765	
Transport Ratio (air)(lb/scf ³)		4.36	

Data Set: F10(A)

	Gasifier	Regenerator	
<u>Bypass</u>			
ΔP_o (in. H_2O)	79.36	73.75	
P_1 (lb/in ² a)	16.3	16.2	
T_1 (°R)	585	580	<u>Note</u>
$P_{Fan Exit}$ (lb/in ² a)	17.3	17.3	†Sample average
$T_{Fan Exit}$ (°R)	585	580	
μ (cp)	0.01937	0.01924	
γ	0.96079	0.96327	
$\dot{Q}_{Bypass}$ (lb/s)	5.930	5.758	
$\dot{M}_{Bypass}$ (lb/h)	21,419	20,728	
<u>Beds</u>			
Amps	135	162	
$\dot{M}_{Total}$ (lb/h)	35,882	37,503	
$\dot{M}_{Fluidizing}$ (lb/h)	14,463	16,775	
T_{Plenum} (°R)	580	580	
P_{Plenum} (lb/in ² a)	15.8	15.8	
ρ_{Plenum} (lb/ft ³)	0.0736	0.0736	
V_{Plenum} (ft/s)	5.64	6.54	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0685	0.0685	
V_{Top} (ft/s)	6.06	7.03	
Display (start/end)	1190/1192	1145/1093	
Bed Wt. (start/end) (lb)	2113/2121	1933/1725	
Bed Ht. (start/end) (in.)	22/23	21/20	
ρ_{Bed} (start/end) (lb/ft ³)	119/114	114/107	
$\dot{Q}_{Op}$ (s)		1020	
<u>Spargers</u>			
T_{Tank} (°R)		544	
P_{Tank} (start/end) (lb/in ² g)		93/63	
ΔP_{Tank} (lb/in ²)		30	
$\Delta \dot{M}_{Total Air}$ (lb)		32.42	
Air Rate (lb/min)		1.91	
$\Delta P_{Annubar}$ (in. H_2O)		0.1034	
$T_{Annubar}$ (°R)		543	
$P_{Annubar}$ (lb/in ² a)		34.7	
$\rho_{Bleed Air}$ (lb/ft ³)		0.1719	
$\dot{M}_{Bleed Air}$ (lb/min)		1.48	
$\dot{M}_{Pulse Air}$ (lb/min)		0.43	
$P_{Sparger}$ (lb/in ² g)		6.75	
Timer (on/off) (s)		1.25/24.4	
Volume (Air) (sft ³ /min)		25.48	
Material Rate (lb/h)		6240	
Transport Ratio (air) (lb/sft ³)		4.08	

Data Set: F10R₁(A)

	Gasifier	Regenerator	
<u>Bypass</u>	78.77	74.05	
ΔP_o (in. H ₂ O)			
P_1 (lb/in ² a)	16.3	16.2	
T_1 (°R)	585	580	Note
$P_{Fan Exit}$ (lb/in ² a)	17.3	17.3	†Sample average
$T_{Fan Exit}$ (°R)	590	580	
μ (cp)	0.01937	0.01924	
η	0.96111	0.96315	
$\dot{Q}_{Bypass}$ (lb/s)	5.930	5.769	
$\dot{Q}_{Bypass}$ (lb/h)	21,347	20,768	
<u>Beds</u>			
Amps	152	165	
$\dot{M}_{Total}$ (lb/h)	35,188	38,197	
$\dot{M}_{Fluidizing}$ (lb/h)	13,841	17,429	
T_{Plenum} (°R)	580	580	
P_{Plenum} (lb/in ² a)	16.5	16.5	
ρ_{Plenum} (lb/ft ³)	0.0770	0.0770	
V_{Plenum} (ft/s)	5.17	6.51	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0685	0.0685	
V_{Top} (ft/s)	5.80	7.31	
Display (start/end)	1230/1155	1118/1150	
Bed Wt. (start/end) (lb)	2273/1973	1825/1953	
Bed Ht. (start/end) (in.)	23/22	20/21	
ρ_{Bed} (start/end) (lb/ft ³)	122/111	113/115	
ϕ_{Op} (s)		900	
<u>Spargers</u>			
T_{Tank} (°R)		544	
P_{Tank} (start/end) (lb/in ² g)		95/67	
ΔP_{Tank} (lb/in ²)		28	
$\Delta \dot{M}_{Total Air}$ (lb)		30.25	
Air Rate (lb/min)		2.02	
$\Delta P_{Annubar}$ (in. H ₂ O)		0.1323	
$T_{Annubar}$ (°R)		544	
$P_{Annubar}$ (lb/in ² a)		34.7	
$\rho_{Bleed Air}$ (lb/ft ³)		0.1722	
$\dot{M}_{Bleed Air}$ (lb/min)		1.68	
$\dot{M}_{Pulse Air}$ (lb/min)		0.34	
$P_{Sparger}$ (lb/in ² g)		6.75	
Timer (on/off) (s)		1.25/24.4	
Volume (Air) (sft ³ /min)		26.93	
Material Rate ⁺ (lb/h)		6675	
Transport Ratio (air) (lb/sft ³)		4.13	

Data Set: FLOR₂(A)

	Gasifier	Regenerator	
<u>Bypass</u>			
ΔP_0 (in. H ₂ O)	79.95	76.64	
P_1 (lb/in ² a)	16.3	16.2	
T_1 (°R)	573	568	Note
$P_{Fan Exit}$ (lb/in ² a)	17.4	17.3	†Sample average
$T_{Fan Exit}$ (°R)	577	568	
μ (cp)	0.01906	0.01893	
γ	0.96035	0.96288	
$\dot{Q}_{Bypass}$ (lb/s)	6.032	5.850	
$\dot{M}_{Bypass}$ (lb/h)	21,716	21,062	
<u>Beds</u>			
Amps	155	165	
$\dot{M}_{Total}$ (lb/h)	36,231	38,568	
$\dot{M}_{Fluidizing}$ (lb/h)	14,315	17,306	
T_{Plenum} (°R)	570	570	
P_{Plenum} (lb/in ² a)	16.5	16.5	
ρ_{Plenum} (lb/ft ³)	0.0781	0.0781	
V_{Plenum} (ft/s)	5.33	6.43	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0697	0.0697	
V_{Top} (ft/s)	5.98	7.21	
Display (start/end)	1147/1137	1175/1136	
Bed Wt. (start/end) (lb)	1941/1901	2053/1897	
Bed Ht. (start/end) (in.)	21	20	
ρ_{Bed} (start/end) (lb/ft ³)	115	127	
θ_{Op} (s)		960	
<u>Spargers</u>			
T_{Tank} (°R)		540	
P_{Tank} (start/end) (lb/in ² g)		95/65	
ΔP_{Tank} (lb/in ²)		30	
$\dot{M}_{Total Air}$ (lb)		32.66	
Air Rate (lb/min)		2.04	
$\Delta P_{Annubar}$ (in. H ₂ O)		0.0827	
$T_{Annubar}$ (°R)		544.5	
$P_{Annubar}$ (lb/in ² a)		34.7	
$\rho_{Bleed Air}$ (lb/ft ³)		0.1721	
$\dot{M}_{Bleed Air}$ (lb/min)		1.33	
$\dot{M}_{Pulse Air}$ (lb/min)		0.67	
$P_{Sparger}$ (lb/in ² g)		6.5	
Timer (on/off) (s)		1.25/24.4	
Volume (Air) (sft ³ /min)		27.25	
Material Rate ⁺ (lb/h)		5200	
Transport Ratio (air)(lb/sft ³)		3.18	

Data Set: DO(A)

	Gasifier	Regenerator	
<u>Bypass</u>			
ΔP_0 (in. H_2O)	82.90	76.70	
P_1 (lb/in ² a)	16.4	16.2	
T_1 (°R)	564	562	Note
$P_{Fan Exit}$ (lb/in ² a)	17.4	17.4	†Sample average
$T_{Fan Exit}$ (°R)	568	560	
μ (cp)	0.01893	0.01877	
γ	0.93920	0.96195	
$\dot{Q}_{Bypass}$ (lb/s)	6.201	5.956	
$\dot{M}_{Bypass}$ (lb/h)	22.323	21.442	
<u>Beds</u>			
Amps	160	165	
$\dot{M}_{Total}$ (lb/h)	37.985	39.172	
$\dot{M}_{Fluidizing}$ (lb/h)	15.662	17.730	
T_{Plenum} (°R)	562	562	
P_{Plenum} (lb/in ² a)	16.4	16.4	
ρ_{Plenum} (lb/ft ³)	0.0788	0.0788	
V_{Plenum} (ft/s)	5.70	6.46	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0706	0.0706	
V_{Top} (ft/s)	6.36	7.20	
Display (start/end)	1181/1184	1158/1147	
Bed Wt. (start/end) (lb)	2077/2089	1985/1941	
Bed Ht. (start/end) (in.)	19/20	19.75/20.0	
ρ_{Bed} (start/end) (lb/ft ³)	135/129	125/120	
ϕ_{Op} (s)		77.3	
<u>Spargers</u>			
T_{Tank} (°R)	534		
P_{Tank} (start/end) (lb/in ² g)			
ΔP_{Tank} (lb/in ²)	5		
$\Delta \dot{M}_{Total Air}$ (lb)	5.30		
Air Rate (lb/min)	4.26		
$\Delta P_{Annubar}$ (in. H_2O)		0.1737	
$T_{Annubar}$ (°R)		534	
$P_{Annubar}$ (lb/in ² a)		34.7	
$\rho_{Bleed Air}$ (lb/ft ³)		0.1754	
$\dot{M}_{Bleed Air}$ (lb/min)		1.94	
$\dot{M}_{Pulse Air}$ (lb/min)		2.32	
$P_{Sparger}$ (lb/in ² g)		7.0	
Timer (on/off) (s)		1.25/5.45	
Volume (Air) (sft ³ /min)		56.90	
Material Rate (lb/h)		11.730	
Transport Ratio (air) (lb/sft ³)		3.44	

Data Set: D2(A)

		Gasifier	Regenerator	
<u>Bypass</u>	ΔP_o (in. H_2O)	83.19	77.00	
	P_1 (lb/in ² a)	16.4	16.2	
	T_1 (°R)	562	557	<u>Note</u>
	$P_{Fan Exit}$ (lb/in ² a)	17.4	17.4	†Sample average
	$T_{Fan Exit}$ (°R)	566	556	
	μ (cp)	0.01877	0.01864	
	γ	0.95908	0.96183	
	$\dot{Q}_{Bypass}$ (lb/s)	6.222	5.993	
	$\dot{N}_{Bypass}$ (lb/h)	22,398	21,577	
<u>Beds</u>	Amps	160	165	
	$\dot{N}_{Total}$ (lb/h)	37,985	39,172	
	$\dot{N}_{Fluidizing}$ (lb/h)	15,587	17,395	
	T_{Plenum} (°R)	559	559	
	P_{Plenum} (lb/in ² a)	16.4	16.4	
	ρ_{Plenum} (lb/ft ³)	0.0792	0.0792	
	V_{Plenum} (ft/s)	5.65	6.37	
	P_{Top} (lb/in ² a)	14.7	14.7	
	ρ_{Top} (lb/ft ³)	0.0710	0.0710	
	V_{Top} (ft/s)	6.30	7.11	
	Display (start/end)	1184/1138	1147/1153	
	Bed Wt. (start/end) (lb)	2089/1905	1941/1965	
	Bed Ht. (start/end) (in.)	20/18	20/20	
	ρ_{Bed} (start/end) (lb/ft ³)	120/131	120/122	
	$\dot{Q}_{Op}$ (s)		300	
<u>Spargers</u>	T_{Tank} (°R)		534	
	P_{Tank} (start/end) (lb/in ² g)		80/63	
	ΔP_{Tank} (lb/in ²)		17	
	$\Delta \dot{N}_{Total Air}$ (lb)		18.71	
	Air Rate (lb/min)		3.74	
	$\Delta P_{Annubar}$ (in. H_2O)		0.1654	
	$T_{Annubar}$ (°R)		536	
	$P_{Annubar}$ (lb/in ² a)		34.7	
	$\rho_{Bleed Air}$ (lb/ft ³)		0.1748	
	$\dot{N}_{Bleed Air}$ (lb/min)		1.89	
	$\dot{N}_{Pulse Air}$ (lb/min)		1.85	
	$P_{Sparger}$ (lb/in ² g)		7.0	
	Timer (on/off) (s)		7.0/5.45	
	Volume (Air) (ft ³ /min)		49.98	
	Material Rate ⁺ (lb/h)		4320	
	Transport Ratio (air) (lb/ft ³)		1.44	

APPENDIX G

CALCULATION SHEETS FOR THE ALTERNATE GASIFIER-REGENERATOR
BED-MATERIAL TRANSFER SLOT--ORIGINAL CONFIGURATION

F292

Data Set: ALT-1

	<u>Gasifier</u>	<u>Regenerator</u>	<u>Notes</u>
<u>Bypass</u>			
ΔP_0 (in. H_2O)			
P_1 (lb/in ² a)			
T_1 ($^{\circ}R$)			
$P_{Fan Exit}$ (lb/in ² a)			*Assumed
$T_{Fan Exit}$ ($^{\circ}R$)			+Sample average
μ (cp)			
Y			
$\dot{Q}_{Bypass}$ (lb/s)			
$\dot{M}_{Bypass}$ (lb/h)			
<u>Beds</u>			
Amps			
$\dot{M}_{Total}$ (lb/h)			
$\dot{M}_{Fluidizing}$ (lb/h)			
T_{Plenum} ($^{\circ}R$)			
P_{Plenum} (lb/in ² a)			
ρ_{Plenum} (lb/ft ³)			
V_{Plenum} (ft/s)			
P_{Top} (lb/in ² a)			
ρ_{Top} (lb/ft ³)			
V_{Top} (ft/s)			
Display (start/end)			
Bed Wt. (start/end) (lb)			
Bed Wt. (start/end) (in.)			
ρ_{Bed} (start/end) (lb/ft ³)			
C_{Op} (s)	81		
<u>Spargers</u>			
T_{Tank} ($^{\circ}R$)	530*		
P_{Tank} (start/end) (lb/in ² g)	65/60		
ΔP_{Tank} (lb/in ²)	5		
$\dot{M}_{Total Air}$ (lb)	5.55		
Air Rate (lb/min)	4.11		
$\Delta P_{Annubar}$ (in. H_2O)	0.2274		
$T_{Annubar}$ ($^{\circ}R$)	545		
$P_{Annubar}$ (lb/in ² a)	32.7		
$\rho_{Bleed Air}$ (lb/ft ³)	0.1620		
$\dot{M}_{Bleed Air}$ (lb/min)	2.14		
$\dot{M}_{Pulse Air}$ (lb/min)	1.97		
$P_{Sparger}$ (lb/in ² g)	2 to 7		
Timer (on/off)(s)			
Volume (Air) (sft ³ /min)	54.85		
Material Rate ⁺ (lb/h)	2210		
Transport Ratio (air) (lb/sft ³)	0.67		

Data Set: ALT-2

	<u>Gasifier</u>	<u>Regenerator</u>
<u>Bypass</u>		
ΔP_o (in. H_2O)		
P_1 (lb/in ² a)		
T_1 (°R)		
$P_{Fan Exit}$ (lb/in ² a)		
$T_{Fan Exit}$ (°R)		
μ (cp)		
γ		
$\dot{Q}_{Bypass}$ (lb/s)		
$\dot{Q}_{Bypass}$ (lb/h)		
<u>Beds</u>		
Amps		
$\dot{H}_{Total}$ (lb/h)		
$\dot{H}_{Fluidizing}$ (lb/h)		
T_{Plenum} (°R)		
P_{Plenum} (lb/in ² a)		
ρ_{Plenum} (lb/ft ³)		
V_{Plenum} (ft/s)		
P_{Top} (lb/in ² a)		
ρ_{Top} (lb/ft ³)		
V_{Top} (ft/s)		
Display (start/end)	1081/973	1140/1185
Bed Wt. (start/end) (lb)		
Bed Ht. (start/end) (in.)	18/16	18/20
ρ_{Bed} (start/end) (lb/ft ³)		
ϕ_{Op} (s)	300	
<u>Spargers</u>		
T_{Tank} (°R)	530*	
P_{Tank} (start/end) (lb/in ² g)	92/75	
ΔP_{Tank} (lb/in ²)	17	
$\Delta \dot{H}_{Total Air}$ (lb)	18.83	
Air Rate (lb/min)	3.77	
$\Delta P_{Annubar}$ (in. H_2O)	0.1654	
$T_{Annubar}$ (°R)	530	
$P_{Annubar}$ (lb/in ² a)	32.7	
$\rho_{Bleed Air}$ (lb/ft ³)	0.1605	
$\dot{H}_{Bleed Air}$ (lb/min)	1.81	
$\dot{H}_{Pulse Air}$ (lb/min)	1.96	
$P_{Sparger}$ (lb/in ² g)	2 to 6	
Timer (on/off) (s)		
Volume (Air) (sft ³ /min)	50.35	
Material Rate (lb/h)	1992	
Transport Ratio (air) (lb/sft ³)	0.66	

Notes

*Assumed
†Sample average

Data Set: ALT-3

	<u>Gasifier</u>	<u>Regenerator</u>	
<u>Bypass</u>			<u>Notes</u>
ΔP_o (in. H_2O)			
P_1 (lb/in ² a)			
T_1 (°R)			
$P_{Fan Exit}$ (lb/in ² a)			*Assumed
$T_{Fan Exit}$ (°R)			*Sample average
μ (cp)			
γ			
$\dot{Q}_{Bypass}$ (lb/s)			
$\dot{N}_{Bypass}$ (lb/h)			
<u>Beds</u>			
Amps			
$\dot{N}_{Total}$ (lb/h)			
$\dot{N}_{Fluidizing}$ (lb/h)			
T_{Plenum} (°R)			
P_{Plenum} (lb/in ² a)			
ρ_{Plenum} (lb/ft ³)			
V_{Plenum} (ft/s)			
P_{Top} (lb/in ² a)			
ρ_{Top} (lb/ft ³)			
V_{Top} (ft/s)			
Display (start/end)			
Bed Wt. (start/end)* (lb)			
Bed Ht. (start/end) (in.)			
ρ_{Bed} (start/end) (lb/ft ³)			
θ_{Op} (s)	72		
<u>Spargers</u>			
T_{Tank} (°R)	530*		
P_{Tank} (start/end) (lb/in ² g)	85/80		
ΔP_{Tank} (lb/in ²)	5		
$\dot{M}_{Total Air}$ (lb)	5.35		
Air Rate (lb/min)	4.62		
$\Delta P_{Annubar}$ (in. H_2O)	0.0827		
$T_{Annubar}$ (°R)	540		
$P_{Annubar}$ (lb/in ² a)	32.7		
$\rho_{Bleed Air}$ (lb/ft ³)	0.1635		
$\dot{N}_{Bleed Air}$ (lb/min)	1.29		
$\dot{N}_{Pulse Air}$ (lb/min)	3.33		
$P_{Sparger}$ (lb/in ² g)	2 to 8		
Timer (on/off) (s)	1.65/1.85		
Volume (Air) (scf ³ /min)	61.71		
Material Rate (lb/h)	1930		
Transport Ratio (air) (lb/scf ³)	0.52		

Data Set: ALT-4

	Gasifier	Regenerator
<u>Bypass</u>	ΔP_o (in. H_2O)	
	P_1 (lb/in ² a)	
	T_1 ($^{\circ}R$)	
	$P_{Fan Exit}$ (lb/in ² a)	
	$T_{Fan Exit}$ ($^{\circ}R$)	
	μ (cp)	
	Y	
	$\dot{Q}_{Bypass}$ (lb/s)	
	$\dot{M}_{Bypass}$ (lb/h)	
<u>Beds</u>	Amps	
	$\dot{M}_{Total}$ (lb/h)	
	$\dot{M}_{Fluidizing}$ (lb/h)	
	T_{Plenum} ($^{\circ}R$)	
	P_{Plenum} (lb/in ² a)	
	ρ_{Plenum} (lb/ft ³)	
	V_{Plenum} (ft/s)	
	P_{Top} (lb/in ² a)	
	ρ_{Top} (lb/ft ³)	
	V_{Top} (ft/s)	
	Display (start/end)	
	Bed Wt. (start/end) (lb)	
	Bed Ht. (start/end) (in.)	
	ρ_{Bed} (start/end) (lb/ft ³)	
	G_{Op} (s)	126
<u>Spargers</u>	T_{Tank} ($^{\circ}R$)	530*
	P_{Tank} (start/end) (lb/in ² g)	95/90
	ΔP_{Tank} (lb/in ²)	3
	$\Delta \dot{M}_{Total Air}$ (lb)	3.35
	Air Rate (lb/min)	2.64
	$\Delta P_{Annubar}$ (in. H_2O)	0.2068
	$T_{Annubar}$ ($^{\circ}R$)	340
	$P_{Annubar}$ (lb/in ² a)	32.7
	$\rho_{Bleed Air}$ (lb/ft ³)	0.1635
	$\dot{M}_{Bleed Air}$ (lb/min)	2.05
	$\dot{M}_{Pulse Air}$ (lb/min)	0.59
	$P_{Sparger}$ (lb/in ² g)	2 to 8
	Timer (on/off) (s)	1.65/13.45
	Volume (Air) (scf ³ /min)	35.26
	Material Rate ⁺ (lb/h)	1200
	Transport Ratio (air) (lb/scf ³)	0.57

Notes

*Assumed
†Sample average

Data Set: ALT-5

	Gasifier	Regenerator	Notes
<u>Bypass</u>			
ΔP_o (in. H_2O)			
P_1 (lb/in ² a)			
T_1 (*R)			
$P_{Fan Exit}$ (lb/in ² a)			*Assumed
$T_{Fan Exit}$ (*R)			†Sample average
μ (cp)			
γ			
$\dot{Q}_{Bypass}$ (lb/s)			
$\dot{M}_{Bypass}$ (lb/h)			
<u>Beds</u>			
Amps			
$\dot{M}_{Total}$ (lb/h)			
$\dot{M}_{Fluidizing}$ (lb/h)			
T_{Plenum} (*R)			
P_{Plenum} (lb/in ² a)			
ρ_{Plenum} (lb/ft ³)			
V_{Plenum} (ft/s)			
F_{Top} (lb/in ² a)			
ρ_{Top} (lb/ft ³)			
V_{Top} (ft/s)			
Display (start/end)			
Bed Wt. (start/end) (lb)			
Bed Ht. (start/end) (in.)			
ρ_{Bed} (start/end) (lb/ft ³)			
C_{Op} (s)	121.5		
<u>Spargers</u>			
T_{Tank} (*R)	530*		
P_{Tank} (start/end) (lb/in ² g)	80/75		
ΔP_{Tank} (lb/in ²)	5		
$\dot{M}_{Total Air}$ (lb)	5.55		
Air Rate (lb/min)	2.74		
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (*R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)	2.74		
$P_{Sparger}$ (lb/in ² g)	0 to 4		
Timer (on/off) (s)	1.65/1.85		
Volume (Air) (scf ³ /min)	36.57		
Material Rate (lb/h)	1470		
Transport Ratio (air) (lb/scf ³)	0.67		

Data Set: ALT-6

	<u>Gasifier</u>	<u>Regenerator</u>	
<u>Bypass</u>	ΔP_o (in. H_2O)		
	P_1 (lb/in ² a)		
	T_1 (°R)		<u>Notes</u>
	$P_{Fan Exit}$ (lb/in ² a)		*Assumed
	$T_{Fan Exit}$ (°R)		†Sample average
	μ (cp)		
	γ		
	$\dot{Q}_{Bypass}$ (lb/s)		
	$\dot{N}_{Bypass}$ (lb/h)		
<u>Beds</u>	ΔP_{Beds}		
	$\dot{Q}_{Total}$ (lb/h)		
	$\dot{Q}_{Fluidizing}$ (lb/h)		
	T_{Plenum} (°R)		
	P_{Plenum} (lb/in ² a)		
	ρ_{Plenum} (lb/ft ³)		
	V_{Plenum} (ft/s)		
	P_{Top} (lb/in ² a)		
	ρ_{Top} (lb/ft ³)		
	V_{Top} (ft/s)		
	Display (start/end)		
	Bed Wt. (start/end) (lb)		
	Bed Ht. (start/end) (in.)		
	ρ_{Bed} (start/end) (lb/ft ³)		
	β_{Op} (s)	66	
<u>Spargers</u>	T_{Tank} (°R)	530*	
	P_{Tank} (start/end) (lb/in ² g)	80/75	
	ΔP_{Tank} (lb/in ²)	3	
	$\dot{N}_{Total Air}$ (lb)	3.55	
	Air Rate (lb/min)	3.04	
	$\Delta P_{Annubar}$ (in. H_2O)		
	$T_{Annubar}$ (°R)		
	$P_{Annubar}$ (lb/in ² a)		
	$\rho_{Bleed Air}$ (lb/ft ³)		
	$\dot{N}_{Bleed Air}$ (lb/min)		
	$\dot{N}_{Pulse Air}$ (lb/min)	3.04	
	$P_{Sparger}$ (lb/in ² g)	2 to 8	
	Timer (on/off) (s)	13.00/1.85	
	Volume (Air) (scf/min)	67.32	
	Material Rate (lb/h)	2100	
	Transport Ratio (air) (lb/scf ³)	0.52	

Data Set: ALT-7

	Gasifier	Regenerator
<u>Bypass</u>		
ΔP_o (in. H_2O)		
P_1 (lb/in ² a)		
T_1 (°R)		
$P_{Fan Exit}$ (lb/in ² a)		
$T_{Fan Exit}$ (°R)		
μ (cp)		
τ		
$\dot{Q}_{Bypass}$ (lb/s)		
$\dot{M}_{Bypass}$ (lb/h)		
<u>Beds</u>		
Amps		
$\dot{M}_{Total}$ (lb/h)		
$\dot{M}_{Fluidizing}$ (lb/h)		
T_{Plenum} (°R)		
P_{Plenum} (lb/in ² a)		
ρ_{Plenum} (lb/ft ³)		
V_{Plenum} (ft/s)		
P_{Top} (lb/in ² a)		
ρ_{Top} (lb/ft ³)		
V_{Top} (ft/s)		
Display (start/end)	1077/967	1048/1159
Bed Wt. (start/end) (lb)		
Bed Ht. (start/end) (in.)	18/13	17/20
ρ_{Bed} (start/end) (lb/ft ³)		
ϕ_{Op} (s)	300	
<u>Spargers</u>		
T_{Tank} (°R)	530*	
P_{Tank} (start/end) (lb/in ² g)	75/55	
ΔP_{Tank} (lb/in ²)	20	
$\dot{M}_{Total Air}$ (lb)	22.18	
Air Rate (lb/min)	4.44	
$\Delta P_{Annubar}$ (in. H_2O)	0.8063	
$T_{Annubar}$ (°R)	550	
$P_{Annubar}$ (lb/in ² a)	32.7	
$\rho_{Bleed Air}$ (lb/ft ³)	0.1605	
$\dot{M}_{Bleed Air}$ (lb/min)	4.00	
$\dot{M}_{Pulse Air}$ (lb/min)		
$P_{Sparger}$ (lb/in ² g)	5	
Timer (on/off) (s)		
Volume (Air) (sft ³ /min)	59.24	
Material Rate [†] (lb/h)	2988	
Transport Ratio (air) (lb/sft ³)	0.84	

Notes

*Assumed

†Sample average

Data Set: ALT-8

	<u>Classifier</u>	<u>Regenerator</u>	
<u>Bypass</u>	ΔP_o (in. H_2O)		
	P_1 (lb/in ² a)		
	T_1 (°R)		
	$P_{Fan Exit}$ (lb/in ² a)		
	$T_{Fan Exit}$ (°R)		
	μ (cp)		
	τ		
	$\dot{Q}_{Bypass}$ (lb/s)		
	$\dot{M}_{Bypass}$ (lb/h)		
<u>Beds</u>	Amps		
	$\dot{M}_{Total}$ (lb/h)		
	$\dot{M}_{Fluidizing}$ (lb/h)		
	T_{Plenum} (°R)		
	P_{Plenum} (lb/in ² a)		
	ρ_{Plenum} (lb/ft ³)		
	V_{Plenum} (ft/s)		
	P_{Top} (lb/in ² a)		
	ρ_{Top} (lb/ft ³)		
	V_{Top} (ft/s)		
	Display (start/end)		
	Bed Wt. (start/end) (lb)		
	Bed Ht. (start/end) (in.)		
	ρ_{Bed} (start/end) (lb/ft ³)		
	ϕ_{Op} (s)	79	
<u>Spargers</u>	T_{Tank} (°R)	530*	
	P_{Tank} (start/end) (lb/in ² g)	78/73	
	ΔP_{Tank} (lb/in ²)	5	
	$\dot{M}_{Total Air}$ (lb)	5.55	
	Air Rate (lb/min)	4.21	
	$\Delta P_{Annubar}$ (in. H_2O)		
	$T_{Annubar}$ (°R)		
	$P_{Annubar}$ (lb/in ² a)		
	$\rho_{Bleed Air}$ (lb/ft ³)		
	$\dot{M}_{Bleed Air}$ (lb/min)		
	$\dot{M}_{Pulse Air}$ (lb/min)	4.21	
	$P_{Sparger}$ (lb/in ² g)	2 to 8	
	Timer (on/off) (s)	1.65/4.40	
	Volume (Air) (ft ³ /min)	56.24	
	Material Rate ⁺ (lb/h)	1980	
	Transport Ratio (air) (lb/ft ³)	0.59	

Notes

*Assumed
†Sample average

Data Set: ALT-9

	Gasifier	Regenerator	Notes
<u>Bypass</u>			
ΔP_0 (in. H_2O)			
P_1 (lb/in ² a)			
T_1 (°R)			
$P_{Fan Exit}$ (lb/in ² a)			*Calculated from annubar reading
$T_{Fan Exit}$ (°R)			†Sample average
μ (cp)			
Y			
$\dot{M}_{Bypass}$ (lb/s)			
$\dot{M}_{Bypass}$ (lb/h)			
<u>Beds</u>			
Amps			
$\dot{M}_{Total}$ (lb/h)			
$\dot{M}_{Fluidizing}$ (lb/h)			
T_{Plenum} (°R)			
P_{Plenum} (lb/in ² a)			
ρ_{Plenum} (lb/ft ³)			
V_{Plenum} (ft/s)			
P_{Top} (lb/in ² a)			
ρ_{Top} (lb/ft ³)			
V_{Top} (ft/s)			
Display (start/end)			
Bed Ht. (start/end) (lb)			
Bed Ht. (start/end) (in.)			
ρ_{Bed} (start/end) (lb/ft ³)			
ϕ_{Op} (s)			
<u>Spargers</u>			
T_{Tank} (°R)			
P_{Tank} (start/end) (lb/in ² g)			
ΔP_{Tank} (lb/in ²)			
$\dot{M}_{Total Air}$ (lb)			
Air Rate (lb/min)	3.87*		
$\Delta P_{Annubar}$ (in. H_2O)	0.7236		
$T_{Annubar}$ (°R)	535		
$P_{Annubar}$ (lb/in ² a)	33.2		
$\rho_{Bleed Air}$ (lb/ft ³)	0.1676		
$\dot{M}_{Bleed Air}$ (lb/min)	3.87		
$\dot{M}_{Pulse Air}$ (lb/min)			
$P_{Sparger}$ (lb/in ² g)	4.8		
Timer (on/off) (s)			
Volume (Air) (sft ³ /min)	51.73		
Material Rate (lb/h)	2250		
Transport Ratio (air) (lb/sft ³)	0.72		

Data Set: ALT-10

	<u>Gasifier</u>	<u>Regenerator</u>	
<u>Bypass</u>	ΔP_o (in. H_2O)		
	P_1 (lb/in ² a)		
	T_1 (°R)		
	$P_{Fan Exit}$ (lb/in ² a)		
	$T_{Fan Exit}$ (°R)		
	μ (cp)		
	γ		
	$\dot{M}_{Bypass}$ (lb/s)		
	$\dot{M}_{Bypass}$ (lb/h)		
<u>Beds</u>	Amps		
	$\dot{M}_{Total}$ (lb/h)		
	$\dot{M}_{Fluidizing}$ (lb/h)		
	T_{Plenum} (°R)		
	P_{Plenum} (lb/in ² a)		
	ρ_{Plenum} (lb/ft ³)		
	V_{Plenum} (ft/s)		
	P_{Top} (lb/in ² a)		
	ρ_{Top} (lb/ft ³)		
	V_{Top} (ft/s)		
	Display (start/end)		
	Bed Wt. (start/end) (lb)		
	Bed Ht. (start/end) (in.)		
	ρ_{Bed} (start/end) (lb/ft ³)		
	G_{Op} (s)		
<u>Spargers</u>	T_{Tank} (°R)		
	P_{Tank} (start/end) (lb/in ² g)		
	ΔP_{Tank} (lb/in ²)		
	$\Delta \dot{M}_{Total Air}$ (lb)		
	Air Rate (lb/min)	5.81*	
	$\Delta P_{Annubar}$ (in. H_2O)	1.6340	
	$T_{Annubar}$ (°R)	535	
	$P_{Annubar}$ (lb/in ² a)	32.7	
	$\rho_{Bleed Air}$ (lb/ft ³)	0.1650	
	$\dot{M}_{Bleed Air}$ (lb/min)	5.81	
	$\dot{M}_{Pulse Air}$ (lb/min)		
	$P_{Sparger}$ (lb/in ² g)	10	
	Timer (on/off) (s)		
	Volume (Air) (scf ³ /min)	77.61	
	Material Rate [†] (lb/h)	2130	
	Transport Ratio (air) (lb/scf ³)	0.46	

Notes

*Calculated from annubar reading
†Sample average

Data Set: ALT-11

	Casifier	Regenerator
<u>Bypass</u>		
ΔP_o (in. H_2O)		
P_1 (lb/in ² a)		
T_1 (°R)		
$P_{Fan Exit}$ (lb/in ² a)		
$T_{Fan Exit}$ (°R)		
μ (cp)		
γ		
$\dot{Q}_{Bypass}$ (lb/s)		
$\dot{Q}_{Bypass}$ (lb/h)		
<u>Beds</u>		
Amps		
$\dot{M}_{Total}$ (lb/h)		
$\dot{M}_{Fluidizing}$ (lb/h)		
T_{Plenum} (°R)		
P_{Plenum} (lb/in ² a)		
ρ_{Plenum} (lb/ft ³)		
V_{Plenum} (ft/s)		
P_{Top} (lb/in ² a)		
ρ_{Top} (lb/ft ³)		
V_{Top} (ft/s)		
Display (start/end)		
Bed Wt. (start/end) (lb)		
Bed Ht. (start/end) (in.)		
ρ_{Bed} (start/end) (lb/ft ³)		
Θ_{Op} (s)		
<u>Spargers</u>		
T_{Tank} (°R)		
P_{Tank} (start/end) (lb/in ² g)		
ΔP_{Tank} (lb/in ²)		
$\Delta \dot{M}_{Total Air}$ (lb)		
Air Rate (lb/min)	2.15*	
$\Delta P_{Annubar}$ (in. H_2O)	0.2274	
$T_{Annubar}$ (°R)	538	
$P_{Annubar}$ (lb/in ² a)	32.7	
$\rho_{Bleed Air}$ (lb/ft ³)	0.1641	
$\dot{M}_{Bleed Air}$ (lb/min)	2.15	
$\dot{M}_{Pulse Air}$ (lb/min)		
$P_{Sparger}$ (lb/in ² g)	2	
Timer (on/off)(s)		
Volume (Air) (scf ³ /min)	28.70	
Material Rate ⁺ (lb/h)	1980	
Transport Ratio (air)(lb/scf ³)	1.15	

Notes

*Calculated from annubar readings
†Sample average

Data Set: ALT-12

	Casifier	Regenerator	Notes
<u>Bypass</u>	ΔP_o (in. H_2O)		
	P_1 (lb/in ² a)		
	T_1 (°R)		
	$P_{Fan Exit}$ (lb/in ² a)		*Calculated from annubar readings
	$T_{Fan Exit}$ (°R)		†Sample average
	μ (cp)		
	γ		
	$\dot{Q}_{Bypass}$ (lb/s)		
	$\dot{M}_{Bypass}$ (lb/h)		
<u>Beds</u>	Amps		
	$\dot{M}_{Total}$ (lb/h)		
	$\dot{M}_{Fluidizing}$ (lb/h)		
	T_{Plenum} (°R)		
	P_{Plenum} (lb/in ² a)		
	ρ_{Plenum} (lb/ft ³)		
	V_{Plenum} (ft ³ /s)		
	P_{Top} (lb/in ² a)		
	ρ_{Top} (lb/ft ³)		
	V_{Top} (ft ³ /s)		
	Display (start/end)		
	Bed Wt. (start/end) (lb)		
	Bed Ht. (start/end) (in.)		
	ρ_{Bed} (start/end) (lb/ft ³)		
	G_{Op} (s)		
<u>Spargers</u>	T_{Tank} (°R)		
	P_{Tank} (start/end) (lb/in ² g)		
	ΔP_{Tank} (lb/in ²)		
	$\dot{M}_{Total Air}$ (lb)		
	Air Rate (lb/min)	3.86*	
	$\Delta P_{Annubar}$ (in. H_2O)	0.7278	
	$T_{Annubar}$ (°R)	535	
	$P_{Annubar}$ (lb/in ² a)	32.7	
	$\rho_{Bleed Air}$ (lb/ft ³)	0.1950	
	$\dot{M}_{Bleed Air}$ (lb/min)	3.86	
	$\dot{M}_{Pulse Air}$ (lb/min)		
	$P_{Sparger}$ (lb/in ² g)	4.8	
	Timer (on/off) (s)		
	Volume (Air) (scf ³ /min)	51.48	
	Material Rate [†] (lb/h)	2618	
	Transport Ratio (air) (lb/scf ³)	0.78	

Data Set: ALT-13

Bypass ΔP_0 (in. H_2O)
 P_1 (lb/in²a)
 T_1 (°R)
 $P_{Fan Exit}$ (lb/in²a)
 $T_{Fan Exit}$ (°R)
 μ (cp)
 γ
 $\dot{Q}_{Bypass}$ (lb/s)
 $\dot{M}_{Bypass}$ (lb/h)
Beds Amps
 $\dot{M}_{Total}$ (lb/h)
 $\dot{M}_{Fluidizing}$ (lb/h)
 T_{Plenum} (°R)
 P_{Plenum} (lb/in²a)
 ρ_{Plenum} (lb/ft³)
 V_{Plenum} (ft/s)
 P_{Top} (lb/in²a)
 ρ_{Top} (lb/ft³)
 V_{Top} (ft/s)
Display (start/end)
Bed Wt. (start/end) (lb)
Bed Ht. (start/end) (in.)
 ρ_{Bed} (start/end) (lb/ft³)
 Θ_{Op} (s)
Spargers T_{Tank} (°R)
 P_{Tank} (start/end) (lb/in²g)
 ΔP_{Tank} (lb/in²)
 $\Delta \dot{M}_{Total Air}$ (lb)
Air Rate (lb/min)
 $\Delta P_{Annubar}$ (in. H_2O)
 $T_{Annubar}$ (°R)
 $P_{Annubar}$ (lb/in²a)
 $\rho_{Bleed Air}$ (lb/ft³)
 $\dot{M}_{Bleed Air}$ (lb/min)
 $\dot{M}_{Pulse Air}$ (lb/min)
 $P_{Sparger}$ (lb/in²g)
Timer (on/off) (s)
Volume (Air) (scf/min)
Material Rate[†] (lb/h)
Transport Ratio (air) (lb/scf³)

Gasifier

Regenerator

Notes

†Sample average

Particle timing (5-in.-diameter tube)

Length (in.)	Time (s)	Material Rate (lb/h)
12	30	1456
9	12	1517
12	27	1618

(Bulk density is assumed equal to 89 lb/ft³)

2 to 8
1.65/4.40

1980

Data Set: ALT-14

	<u>Gasifier</u>	<u>Regenerator</u>
<u>Bypass</u>		
ΔP_o (in. H_2O)		
P_1 (lb/in ² a)		
T_1 (°R)		
$P_{Fan Exit}$ (lb/in ² a)		
$T_{Fan Exit}$ (°R)		
μ (cp)		
γ		
$\dot{Q}_{Bypass}$ (lb/s)		
$\dot{M}_{Bypass}$ (lb/h)		
<u>Beds</u>		
Amps		
$\dot{M}_{Total}$ (lb/h)		
$\dot{M}_{Fluidising}$ (lb/h)		
T_{Plenum} (°R)		
P_{Plenum} (lb/in ² a)		
ρ_{Plenum} (lb/ft ³)		
V_{Plenum} (ft/s)		
P_{Top} (lb/in ² a)		
ρ_{Top} (lb/ft ³)		
V_{Top} (ft/s)		
Display (start/end)		
Bed Wt. (start/end) (lb)		
Bed Ht. (start/end) (in.)		
ρ_{Bed} (start/end) (lb/ft ³)		
Θ_{Op} (s)		
<u>Spargers</u>		
T_{Tank} (°R)		
P_{Tank} (start/end) (lb/in ² g)		
ΔP_{Tank} (lb/in ²)		
$\dot{M}_{Total Air}$ (lb)		
Air Rate (lb/min)	1.97*	
$\Delta P_{Annubar}$ (in. H_2O)	0.1861	
$T_{Annubar}$ (°R)	540	
$P_{Annubar}$ (lb/in ² a)	33.7	
$\rho_{Bleed Air}$ (lb/ft ³)	0.1683	
$\dot{M}_{Bleed Air}$ (lb/min)	1.97	
$\dot{M}_{Pulse Air}$ (lb/min)		
$P_{Sparger}$ (lb/in ² g)	5	
Timer (on/off) (s)		
Volume (Air) (scf ³ /min)	26.31	
Material Rate [†] (lb/h)	2333	
Transport Ratio (air) (lb/scf ³)	1.48	

Notes

*Calculated from annubar readings
†Sample average

Particle timing (3-in.-diameter tube)

Length (in.)	Time (s)	Material Rate (lb/h)
12	27	1618
12	31	1409
6	13.5	1618
10	24.5	1486

(Bulk density is assumed equal to 89 lb/ft³)

Data Set: ALT-15

	Gasifier	Regenerator
<u>Bypass</u>		
ΔP_o (in. H_2O)		
P_1 (lb/in ² a)		
T_1 (°R)		
$P_{Fan Exit}$ (lb/in ² a)		
$T_{Fan Exit}$ (°R)		
μ (cp)		
γ		
$\dot{Q}_{Bypass}$ (lb/s)		
$\dot{Q}_{Bypass}$ (lb/h)		
<u>Beds</u>		
Amps		
$\dot{Q}_{Total}$ (lb/h)		
$\dot{Q}_{Fluidizing}$ (lb/h)		
T_{Plenum} (°R)		
P_{Plenum} (lb/in ² a)		
ρ_{Plenum} (lb/ft ³)		
V_{Plenum} (ft/s)		
P_{Top} (lb/in ² a)		
ρ_{Top} (lb/ft ³)		
V_{Top} (ft/s)		
Display (start/end)		
Bed Wt. (start/end) (lb)		
Bed Ht. (start/end) (in.)		
ρ_{Bed} (start/end) (lb/ft ³)		
ϕ_{Op} (s)		
<u>Soargers</u>		
T_{Tank} (°R)		
P_{Tank} (start/end) (lb/in ² g)		
ΔP_{Tank} (lb/in ²)		
$\dot{M}_{Total Air}$ (lb)		
Air Rate (lb/min)	3.77*	
$\Delta P_{Annubar}$ (in. H_2O)	0.6823	
$T_{Annubar}$ (°R)	540	
$P_{Annubar}$ (lb/in ² a)	33.7	
$\rho_{Bleed Air}$ (lb/ft ³)	0.1685	
$\dot{Q}_{Bleed Air}$ (lb/min)	3.77	
$\dot{Q}_{Pulse Air}$ (lb/min)		
$P_{Sparger}$ (lb/in ² g)	13/14	
Timer (on/off) (s)		
Volume (Air) (sft ³ /min)	50.37	
Material Rate [†] (lb/h)	2490	
Transport Ratio (air) (lb/sft ³)	0.82	

Notes

*Calculated from annubar readings

†Sample average

Particle timing (5-in.-diameter tube)

Length (in.)	Time (s)	Material Rate (lb/h)
12	19	2299
12	18	2427
12	17	2570

(Bulk density is assumed equal to 89 lb/ft³)

APPENDIX H
CALCULATION SHEETS FOR THE FINAL GASIFIER-REGENERATOR BED-
MATERIAL TRANSFER SLOT--PERFORATED-PLATE SPARGER

Data Set: L0

		Gasifier	Regenerator	
<u>Bypass</u>	ΔP_o (in. H_2O)	80.24	73.75	
	P_1 (lb/in ² a)	16.3	16.3	
	T_1 (°R)	572	572	<u>Note</u>
	$P_{Fan Exit}$ (lb/in ² a)	17.4		†Sample average
	$T_{Fan Exit}$ (°R)	578	572	
	μ (cp)	0.01903	0.01903	
	γ	0.96040	0.96354	
	$\dot{Q}_{Bypass}$ (lb/s)	6.047	5.817	
	$\dot{M}_{Bypass}$ (lb/h)	21,770	20,942	
<u>Beds</u>	Amps	163	153	
	$\dot{M}_{Total}$ (lb/h)	38,568	36,231	
	$\dot{M}_{Fluidizing}$ (lb/h)	16,798	15,289	
	T_{Plenum} (°R)	574	576	
	P_{Plenum} (lb/in ² a)	16.6	16.6	
	ρ_{Plenum} (lb/ft ³)	0.0781	0.0778	
	V_{Plenum} (ft/s)	6.17	5.64	
	P_{Top} (lb/in ² a)	14.7	14.7	
	ρ_{Top} (lb/ft ³)	0.0691	0.0689	
	V_{Top} (ft/s)	6.97	6.37	
	Display (start/end)			
	Bed Wt. (start/end) (lb)			
	Bed Ht. (start/end) (in.)			
	ρ_{Bed} (start/end) (lb/ft ³)			
	$\odot_{Op}$ (s)		120	
<u>Spargers</u>	T_{Tank} (°R)		537	
	P_{Tank} (start/end) (lb/in ² g)		68/63	
	ΔP_{Tank} (lb/in ²)		5	
	$\Delta \dot{M}_{Total Air}$ (lb)		5.47	
	Air Rate (lb/min)		2.74	
	$\Delta P_{Annubar}$ (in. H_2O)			
	$T_{Annubar}$ (°R)			
	$P_{Annubar}$ (lb/in ² a)			
	$\rho_{Bleed Air}$ (lb/ft ³)			
	$\dot{M}_{Bleed Air}$ (lb/min)			
	$\dot{M}_{Pulse Air}$ (lb/min)		2.74	
	$P_{Sparger}$ (lb/in ² g)		0 to 3	
	Timer (on/off) (s)		0.5/1.85	
	Volume (Air) (cft ³ /min)		36.54	
	Material Rate (lb/h)		20,080	
	Transport Ratio (air) (lb/cft ³)		9.16	

Data Set: LOR₁

	Gasifier	Regenerator	
<u>Bypass</u>	79.65	73.75	
ΔP_o (in. H ₂ O)			
P_1 (lb/in ² a)	16.3	16.2	
T_1 (°R)	577	572	<u>Note</u>
$P_{Fan Exit}$ (lb/in ² a)	17.3		†Sample average
$T_{Fan Exit}$ (°R)	576	566	
μ (cp)	0.01916	0.01903	
γ	0.96064	0.96327	
$\dot{Q}_{Bypass}$ (lb/a)	6.001	5.798	
$\dot{Q}_{Bypass}$ (lb/h)	21,602	20,872	
<u>Beds</u>			
Amps	150	160	
$\dot{Q}_{Total}$ (lb/h)	33,912	36,172	
$\dot{Q}_{Fluidizing}$ (lb/h)	12,310	15,300	
T_{Plenum} (°R)	565	567	
P_{Plenum} (lb/in ² a)	16.4	16.4	
ρ_{Plenum} (lb/ft ³)	0.0784	0.0781	
V_{Plenum} (ft/s)	4.51	5.62	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0702	0.0700	
V_{Top} (ft/s)	5.03	6.27	
Display (start/end)	1232	1132	
Bed Wt. (start/end) (lb)	2281	1881	
Bed Ht. (start/end) (in.)			
ρ_{Bed} (start/end) (lb/ft ³)			
$\dot{Q}_{Op}$ (a)		96.5	
<u>Spargers</u>			
T_{Tank} (°R)		538	
P_{Tank} (start/end) (lb/in ² g)			
ΔP_{Tank} (lb/in ²)		5	
$\dot{M}_{Total Air}$ (lb)		5.46	
Air Rate (lb/min)		3.40	
$\Delta P_{Annubar}$ (in. H ₂ O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{Q}_{Pulse Air}$ (lb/min)		3.40	
$P_{Sparger}$ (lb/in ² g)		3	
Timer (on/off) (s)		0.5/1.85	
Volume (Air) (ft ³ /min)		45.36	
Material Rate ⁺ (lb/h)		19,880	
Transport Ratio (air) (lb/ft ³)		7.31	

Data Set: LOR₂

		<u>Gasifier</u>	<u>Regenerator</u>	
<u>Bypass</u>	ΔP_o (in. H ₂ O)	81.42	75.82	
	P_1 (lb/in ² a)	16.3	16.2	
	T_1 (*R)	571	569	<u>Note</u>
	$F_{Fan Exit}$ (lb/in ² a)	17.4		+Sample average
	$T_{Fan Exit}$ (*R)	574	567	
	μ (cp)	0.01901	0.01896	
	γ	0.95987	0.96234	
	$\dot{Q}_{Bypass}$ (lb/s)	6.093	5.888	
	$\dot{M}_{Bypass}$ (lb/h)	21,936	21,197	
<u>Beds</u>	Amps	165	165	
	$\dot{M}_{Total}$ (lb/h)	39,757	39,757	
	$\dot{M}_{Fluidizing}$ (lb/h)	17,821	18,560	
	T_{Plenum} (*R)	570	570	
	P_{Plenum} (lb/in ² a)	16.8	16.8	
	ρ_{Plenum} (lb/ft ³)	0.0796	0.0796	
	V_{Plenum} (ft/s)	6.42	6.69	
	P_{Top} (lb/in ² a)	14.7	14.7	
	ρ_{Top} (lb/ft ³)	0.0696	0.0696	
	V_{Top} (ft/s)	7.34	7.65	
	Display (start/end)			
	Bed Wt. (start/end) (lb)			
	Bed Ht. (start/end) (in.)			
	ρ_{Bed} (start/end) (lb/ft ³)			
	θ_{Op} (s)		136.9	
	T_{Tank} (*R)		538	
<u>Spargers</u>	P_{Tank} (start/end) (lb/in ²)		5	
	ΔP_{Tank} (lb/in ²)		5.46	
	$\dot{M}_{Total Air}$ (lb)		2.39	
	Air Rate (lb/min)			
	$\Delta P_{Annubar}$ (in. H ₂ O)			
	$T_{Annubar}$ (*R)			
	$P_{Annubar}$ (lb/in ² a)			
	$\rho_{Bleed Air}$ (lb/ft ³)			
	$\dot{M}_{Bleed Air}$ (lb/min)		2.39	
	$\dot{M}_{Pulse Air}$ (lb/min)		3.5/4.1	
	$P_{Sparger}$ (lb/in ² g)		0.3/1.85	
	Timer (on/off) (s)		31.97	
	Volume (Air) (scf ³ /min)		18,400	
	Material Rate ⁺ (lb/h)		9.59	
	Transport Ratio (air) (lb/scf ³)			

Data Set: L1

	Gasifier	Regenerator	
<u>Bypass</u>	80.24	74.05	
ΔP_o (in. H_2O)	16.3	16.2	
P_1 (lb/in ² a)	570	568	Note
T_1 (°R)	17.4		†Sample average
$P_{Fan Exit}$ (lb/in ² a)	573	567	
$T_{Fan Exit}$ (°R)	0.01898	0.01893	
μ (cp)	0.96040	0.96317	
γ	6.058	5.829	
$\dot{Q}_{Bypass}$ (lb/s)	21,808	20,985	
$\dot{M}_{Bypass}$ (lb/h)	162	162	
<u>Beds</u>			
Amps	38,343	38,343	
$\dot{M}_{Total}$ (lb/h)	16,535	17,538	
$\dot{M}_{Fluidizing}$ (lb/h)	570	571	
T_{Plenum} (°R)	16.8	16.8	
P_{Plenum} (lb/in ² a)	0.0796	0.0794	
ρ_{Plenum} (lb/ft ³)	5.96	6.27	
V_{Plenum} (ft/s)	14.7	14.7	
P_{Top} (lb/in ² a)	0.0696	0.0695	
ρ_{Top} (lb/ft ³)	6.81	7.16	
V_{Top} (ft/s)	1149	1193	
Display (start/end)	1949	2125	
Bed Wt. (start/end) (lb)			
Bed Ht. (start/end) (in.)			
ρ_{Bed} (start/end) (lb/ft ³)			
$\dot{Q}_{Op}$ (s)		165.7	
<u>Spargers</u>		538	
T_{Tank} (°R)			
P_{Tank} (start/end) (lb/in ² g)			
ΔP_{Tank} (lb/in ²)		5	
$\Delta \dot{M}_{Total Air}$ (lb)		5.46	
Air Rate (lb/min)		1.98	
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\dot{Q}_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)			
$P_{Sparger}$ (lb/in ² g)		3/3.5	
Timer (on/off) (s)		0.5/3.5	
Volume (Air) (scf ³ /min)		26.41	
Material Rate [†] (lb/h)		16,160	
Transport Ratio (air) (lb/scf ³)		10.20	

Data Set: L1R₁

	Gasifier	Regenerator	
<u>Bypass</u>			
ΔP_o (in. H ₂ O)	82.90	77.00	
P_1 (lb/in ² a)	16.4	16.2	
T_1 (°R)	565	560	Note
$P_{Fan Exit}$ (lb/in ² a)	17.4		†Sample average
$T_{Fan Exit}$ (°R)	570	560	
μ (cp)	0.01885	0.01872	
γ	0.93920	0.96181	
$\dot{Q}_{Bypass}$ (lb/s)	6.195	5.977	
$\dot{M}_{Bypass}$ (lb/h)	22,303	21,519	
<u>Beds</u>			
Amps	160	168	
$\dot{M}_{Total}$ (lb/h)	38,328	40,244	
$\dot{Q}_{Fluidizing}$ (lb/h)	16,025	18,725	
T_{Plenum} (°R)	565	564	
P_{Plenum} (lb/in ² a)	16.6	16.6	
ρ_{Plenum} (lb/ft ³)	0.0793	0.0793	
V_{Plenum} (ft/s)	5.80	6.76	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0702	0.0704	
V_{Top} (ft/s)	6.54	7.63	
Display (start/end)	1142	1059	
Bed Wt. (start/end) (lb)	1921	1590	
Bed Ht. (start/end) (in.)	19.0	17.25	
ρ_{Bed} (start/end) (lb/ft ³)	125	114	
θ_{Op} (s)		305	
<u>Spargers</u>		538	
T_{Tank} (°R)			
P_{Tank} (start/end) (lb/in ² g)			
ΔP_{Tank} (lb/in ²)		5	
$\Delta \dot{M}_{Total Air}$ (lb)		5.46	
Air Rate (lb/min)		1.07	
$\Delta P_{Annubar}$ (in. H ₂ O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)			
$P_{Sparger}$ (lb/in ² g)		3.5/4.0	
Timer (on/off) (s)		0.2/3.4	
Volume (Air) (scf ³ /min)		14.35	
Material Rate ⁺ (lb/h)		7590	
Transport Ratio (air) (lb/scf ³)		8.81	

Data Set: L1R₂

		Gasifier	Regenerator	
<u>Bypass</u>	ΔP_o (in. H ₂ O)	82.60	75.82	
	P_1 (lb/in ² a)	16.3	16.2	
	T_1 (°R)	566	564	Note
	$P_{Fan Exit}$ (lb/in ² a)	17.4		†Sample average
	$T_{Fan Exit}$ (°R)	570	562	
	μ (cp)	0.01888	0.01883	
	γ	0.95932	0.96234	
	$\dot{Q}_{Bypass}$ (lb/s)	6.161	5.914	
	$\dot{M}_{Bypass}$ (lb/h)	22,178	21,290	
<u>Beds</u>	Amps	165	165	
	$\dot{M}_{Total}$ (lb/h)	39,757	39,757	
	$\dot{M}_{Fluidizing}$ (lb/h)	17,379	18,467	
	T_{Plenum} (°R)	564	563	
	P_{Plenum} (lb/in ² a)	16.6	16.6	
	ρ_{Plenum} (lb/ft ³)	0.0795	0.0793	
	V_{Plenum} (ft/s)	6.35	6.68	
	P_{Top} (lb/in ² a)	14.7	14.7	
	ρ_{Top} (lb/ft ³)	0.0704	0.0702	
	V_{Top} (ft/s)	7.17	7.54	
	Display (start/end)	1226	1077	
	Bed Wt. (start/end) (lb)	2257	1661	
	Bed Ht. (start/end) (in.)	19/18	17.25/18	
	ρ_{Bed} (start/end) (lb/ft ³)	147	119	
	Θ_{Op} (s)		342	
<u>Spargers</u>	T_{Tank} (°R)		538	
	P_{Tank} (start/end) (lb/in ² g)		60/55	
	ΔP_{Tank} (lb/in ²)		5	
	$\dot{M}_{Total Air}$ (lb)		5.46	
	Air Rate (lb/min)		0.96	
	$\Delta P_{Annubar}$ (in. H ₂ O)			
	$T_{Annubar}$ (°R)			
	$P_{Annubar}$ (lb/in ² a)			
	$\rho_{Bleed Air}$ (lb/ft ³)			
	$\dot{M}_{Bleed Air}$ (lb/min)			
	$\dot{M}_{Pulse Air}$ (lb/min)			
	$P_{Sparger}$ (lb/in ² g)		3/3.5	
	Timer (on/off) (s)		0.4/3.5	
	Volume (Air) (scf ³ /min)		12.80	
	Material Rate [†] (lb/h)		6120	
	Transport Ratio (air) (lb/scf ³)		7.97	

Data Set: L2

	Gasifier	Regenerator
<u>Bypass</u>	81.13	74.93
ΔP_o (in. H_2O)	16.3	16.2
P_1 (lb/in ² a)	566	564
T_1 (°R)	17.4	16.2
$P_{Fan Exit}$ (lb/in ² a)	571	564
$T_{Fan Exit}$ (°R)	0.01888	0.01883
μ (cp)	0.95994	0.96276
γ	6.110	5.882
$\dot{Q}_{Bypass}$ (lb/s)	21.995	21.174
$\dot{N}_{Bypass}$ (lb/h)	165	165
<u>Beds</u>	165	165
Amps	39,737	39,737
$\dot{N}_{Total}$ (lb/h)	17,762	18,583
$\dot{N}_{Fluidizing}$ (lb/h)	567	564
T_{Plenum} (°R)	16.8	16.8
P_{Plenum} (lb/in ² a)	0.0800	0.0804
ρ_{Plenum} (lb/ft ³)	6.37	6.63
V_{Plenum} (ft/s)	14.7	14.7
P_{Top} (lb/in ² a)	0.0700	0.0704
ρ_{Top} (lb/ft ³)	7.28	7.38
V_{Top} (ft/s)	1254	1059
Display (start/end)	2369	1590
Bed Wt. (start/end) (lb)		
Bed Ht. (start/end) (in.)		
ρ_{Bed} (start/end) (lb/ft ³)		
G_{Op} (s)		231.2
<u>Spargers</u>		338
T_{Tank} (°R)		
P_{Tank} (start/end) (lb/in ² g)		
ΔP_{Tank} (lb/in ²)		5
$\Delta \dot{N}_{Total Air}$ (lb)		5.46
Air Rate (lb/min)		1.42
$\Delta P_{Annubar}$ (in. H_2O)		
$T_{Annubar}$ (°R)		
$P_{Annubar}$ (lb/in ² a)		
$\rho_{Bleed Air}$ (lb/ft ³)		
$\dot{N}_{Bleed Air}$ (lb/min)		
$\dot{N}_{Pulse Air}$ (lb/min)		
$P_{Sparger}$ (lb/in ² g)		3.0
Timer (on/off) (s)		0.3/6.30
Volume (Air) (scf ³ /min)		18.93
Material Rate ⁺ (lb/h)		7650
Transport Ratio (air) (lb/scf ³)		6.73

Note

†Sample average

Data Set: L3

	<u>Gasifier</u>	<u>Regenerator</u>	
<u>Bypass</u>			
ΔP_o (in. H_2O)	80.34	74.64	
P_1 (lb/in ² a)	16.3	16.2	
T_1 (°R)	566	564	<u>Note</u>
$P_{Fan Exit}$ (lb/in ² a)	17.4		+3 sample average
$T_{Fan Exit}$ (°R)	571	563	
μ (cp)	0.01886	0.01883	
γ	0.96026	0.96290	
$\dot{Q}_{Bypass}$ (lb/s)	6.089	5.871	
$\dot{M}_{Bypass}$ (lb/h)	21.921	21.135	
<u>Beds</u>			
Amps	162	165	
$\dot{M}_{Total}$ (lb/h)	38,692	39,408	
$\dot{M}_{Fluidizing}$ (lb/h)	16,771	18,273	
T_{Plenum} (°R)	567	567	
P_{Plenum} (lb/in ² a)	16.8	16.8	
ρ_{Plenum} (lb/ft ³)	0.0800	0.0800	
V_{Plenum} (ft/s)	6.01	6.35	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0700	0.0700	
V_{Top} (ft/s)	6.87	7.49	
Display (start/end)	1180	1152	
Bed Wt. (start/end) (lb)	2073	1961	
Bed Ht. (start/end) (in.)			
ρ_{Bed} (start/end) (lb/ft ³)			
G_{Op} (s)	349.2		
<u>Spargers</u>			
T_{Tank} (°R)	538		
P_{Tank} (start/end) (lb/in ² g)			
ΔP_{Tank} (lb/in ²)	5		
$\dot{M}_{Total Air}$ (lb)	5.46		
Air Rate (lb/min)	0.94		
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)			
$P_{Sparger}$ (lb/in ² g)		3 to 4	
Timer (on/off) (s)		0.5/8.80	
Volume (Air) (scf/min)		12.53	
Material Rate ⁺ (lb/h)		2960	
Transport Ratio (air) (lb/scf ¹)		3.94	

APPENDIX I
CALCULATION SHEETS FOR THE FINAL GASIFIER-REGENERATOR BED-
MATERIAL TRANSFER SLOT--THREE-TUBE SPARGER

Data Set: LS-1

	Gasifier	Regenerator	
<u>Bypass</u>			
ΔP_0 (in. H_2O)	82.60	76.41	
P_1 (lb/in ² a)	16.4	16.2	
T_1 (°R)	559	555	Note
$P_{Fan Exit}$ (lb/in ² a)	17.4		*Assumed
$T_{Fan Exit}$ (°R)	563	555	+Sample average
μ (cp)	0.01870	0.01859	
Y	0.95937	0.96207	
$\dot{Q}_{Bypass}$ (lb/s)	6.218	5.983	
$\dot{N}_{Bypass}$ (lb/h)	22,385	21,538	
<u>Beds</u>			
Amps	160	165	
$\dot{N}_{Total}$ (lb/h)	37,985	39,172	
$\dot{N}_{Fluidizing}$ (lb/h)	15,600	17,634	
T_{Plenum} (°R)	557	557	
P_{Plenum} (lb/in ² a)	16.5	16.5	
ρ_{Plenum} (lb/ft ³)	0.0800	0.0800	
V_{Plenum} (ft/s)	5.60	6.33	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0713	0.0713	
V_{Top} (ft/s)	6.28	7.10	
Display (start/end)	1124	1019	
Bed Wt. (start/end) (lb)	1849	1512	
Bed Ht. (start/end) (in.)			
ρ_{Bed} (start/end) (lb/ft ³)			
$\dot{Q}_{Op}$ (s)	208.3		
<u>Spargers</u>			
T_{Tank} (°R)	535*		
P_{Tank} (start/end) (lb/in ² g)	80/75		
ΔP_{Tank} (lb/in ²)	5		
$\Delta \dot{N}_{Total Air}$ (lb)	5.49		
Air Rate (lb/min)	1.58		
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{N}_{Bleed Air}$ (lb/min)			
$\dot{N}_{Pulse Air}$ (lb/min)	1.58		
$P_{Sparger}$ (lb/in ² g)	2.5		
Timer (on/off)(s)	0.3/7.5		
Volume (Air) (scf ³ /min)	21.13		
Material Rate ⁺ (lb/h)	10,605		
Transport Ratio (air)(lb/scf ³)	8.36		

Data Set: LS-2

	<u>Gasifier</u>	<u>Regenerator</u>	
<u>Bypass</u>	82.60	76.70	
ΔP_0 (in. H_2O)			
P_1 (lb/in ² a)	16.4	16.2	
T_1 (°R)	561	558	Notes
$P_{Fan Exit}$ (lb/in ² a)	17.4		
$T_{Fan Exit}$ (°R)	565	557	*Assumed †Sample average
μ (cp)	0.01875	0.01867	
γ	0.95933	0.96195	
$\dot{Q}_{Bypass}$ (lb/s)	6.207	5.977	
$\dot{M}_{Bypass}$ (lb/h)	22,345	21,518	
<u>Beds</u>			
Amps	160	165	
$\dot{M}_{Total}$ (lb/h)	37,985	39,172	
$\dot{M}_{Fluidizing}$ (lb/h)	15,640	17,634	
T_{Plenum} (°R)	560	560	
P_{Plenum} (lb/in ² a)	16.5	16.5	
ρ_{Plenum} (lb/ft ³)	0.0796	0.0796	
V_{Plenum} (ft/s)	5.64	6.37	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0709	0.0709	
V_{Top} (ft/s)	6.33	7.13	
Display (start/end)			
Bed Wt. (start/end) (lb)			
Bed Ht. (start/end) (ft.)			
ρ_{Bed} (start/end) (lb/ft ³)			
θ_{Op} (s)	225.3		
<u>Spargers</u>			
T_{Tank} (°R)	535*		
P_{Tank} (start/end) (lb/in ² g)			
ΔP_{Tank} (lb/in ²)	5		
$\dot{M}_{Total Air}$ (lb)	5.49		
Air Rate (lb/min)	1.46		
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)	1.46		
$P_{Sparger}$ (lb/in ² g)	2.5		
Timer (on/off) (s)	0.7/9.2		
Volume (Air) (scf ³ /min)	19.54		
Material Rate [†] (lb/h)	9600		
Transport Ratio (air) (lb/scf ³)	8.19		

Data Set: Ls-3

	Gasifier	Regenerator	
<u>Bypass</u>			
ΔP_0 (in. H_2O)	82.6	76.7	
P_1 (lb/in ² a)	16.4	16.2	
T_1 (*R)	561	558	<u>Notes</u>
$P_{Fan Exit}$ (lb/in ² a)	17.4		*Assumed
$T_{Fan Exit}$ (*R)	565	557	†Sample average
μ (cp)	0.01873	0.01867	
	0.95935	0.96195	
$\dot{Q}_{Bypass}$ (lb/s)	6.207	5.977	
$\dot{M}_{Bypass}$ (lb/h)	22,345	21,518	
<u>Beds</u>			
Amps	160	165	
$\dot{M}_{Total}$ (lb/h)	37,985	39,172	
$\dot{M}_{Fluidizing}$ (lb/h)	15,640	17,654	
T_{Plenum} (*R)	560	560	
P_{Plenum} (lb/in ² a)	16.5	16.5	
ρ_{Plenum} (lb/ft ³)	0.0796	0.0796	
V_{Plenum} (ft/s)	5.64	6.37	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0709	0.0709	
V_{Top} (ft/s)	6.33	7.15	
Display (start/end)			
Bed Wt. (start/end) (lb)			
Bed Ht. (start/end) (in.)			
ρ_{Bed} (start/end) (lb/ft ³)			
ω_{Op} (s)	288.3		
<u>Spargers</u>			
T_{Tank} (*R)	535*		
P_{Tank} (start/end) (lb/in ² g)	79/74		
ΔP_{Tank} (lb/in ²)	5		
$\dot{M}_{Total Air}$ (lb)	5.49		
Air Rate (lb/min)	1.14		
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (*R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{Q}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)	1.14		
$P_{Sparger}$ (lb/in ² g)	2.5		
Timer (on/off) (s)	0.5/12		
Volume (Air) (scf ³ /min)	15.27		
Material Rate ⁺ (lb/h)	6840		
Transport Ratio (air) (lb/scf ³)	7.47		

Data Set: LS-4

	Gasifier	Regenerator	
<u>Bypass</u>			
ΔP_0 (in. H_2O)	82.6	76.7	
P_1 (lb/in ² a)	16.4	16.2	
T_1 (°R)	557	555	Note
$P_{Fan Exit}$ (lb/in ² a)	17.5		+Sample average
$T_{Fan Exit}$ (°R)	563	554	
μ (cp)	0.01864	0.01859	
η	0.95937	0.96195	
$\dot{Q}_{Bypass}$ (lb/s)	6.229	5.993	
$\dot{M}_{Bypass}$ (lb/h)	22,425	21,576	
<u>Beds</u>			
Amps	162	165	
$\dot{M}_{Total}$ (lb/h)	38,692	39,408	
$\dot{M}_{Fluidizing}$ (lb/h)	16,267	17,832	
T_{Plenum} (°R)	557	557	
P_{Plenum} (lb/in ² a)	16.5	16.5	
ρ_{Plenum} (lb/ft ³)	0.0800	0.0800	
V_{Plenum} (ft/s)	5.83	6.40	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0713	0.0713	
V_{Top} (ft/s)	6.55	7.18	
Display (start/end)			
Bed Wt. (start/end) (lb)			
Bed Ht. (start/end) (in.)			
ρ_{Bed} (start/end) (lb/ft ³)			
ϕ_{Op} (s)	84		
<u>Spargers</u>			
T_{Tank} (°R)	530		
P_{Tank} (start/end) (lb/in ² g)			
ΔP_{Tank} (lb/in ²)	5		
$\dot{M}_{Total Air}$ (lb)	5.55		
Air Rate (lb/min)	3.96		
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)	3.96		
$P_{Sparger}$ (lb/in ² g)	2.5		
Timer (on/off) (s)	0.5/2.6		
Volume (Air) (sft ³ /min)	52.89		
Material Rate (lb/h)	18,880		
Transport Ratio (air) (lb/sft ³)	3.95		

Data Set: LS-4R

		Gasifier	Regenerator	
<u>Bypass</u>	ΔP_o (in. H_2O)	82.6	76.7	
	P_1 (lb/in ² a)	16.4	16.2	
	T_1 (°R)	558	558	Note
	$P_{Fan Exit}$ (lb/in ² a)	17.3		†Sample average
	$T_{Fan Exit}$ (°R)	563	557	
	μ (cp)	0.01867	0.01867	
	γ	0.93937	0.96195	
	$\dot{Q}_{Bypass}$ (lb/s)	6.224	3.977	
	$\dot{M}_{Bypass}$ (lb/h)	22,403	21,318	
<u>Beds</u>	Amps	170	160	
	$\dot{M}_{Total}$ (lb/h)	40,962	38,352	
	$\dot{M}_{Fluidizing}$ (lb/h)	18,557	17,034	
	T_{Plenum} (°R)	559	560	
	P_{Plenum} (lb/in ² a)	16.7	16.7	
	ρ_{Plenum} (lb/ft ³)	0.0807	0.0805	
	V_{Plenum} (ft/s)	6.60	6.07	
	P_{Top} (lb/in ² a)	14.7	14.7	
	ρ_{Top} (lb/ft ³)	0.0710	0.0709	
	V_{Top} (ft/s)	7.50	6.90	
	Display (start/end)			
	Bed Wt. (start/end) (lb)			
	Bed Ht. (start/end) (in.)			
	ρ_{Bed} (start/end) (lb/ft ³)			
	θ_{Op} (s)	91		
<u>Spargers</u>	T_{Tank} (°R)	330		
	P_{Tank} (start/end) (lb/in ² g)			
	ΔP_{Tank} (lb/in ²)	5		
	$\Delta \dot{M}_{Total Air}$ (lb)	5.35		
	Air Rate (lb/min)	3.66		
	$\Delta P_{Annubar}$ (in. H_2O)			
	$T_{Annubar}$ (°R)			
	$P_{Annubar}$ (lb/in ² a)			
	$\rho_{Bleed Air}$ (lb/ft ³)			
	$\dot{M}_{Bleed Air}$ (lb/min)			
	$\dot{M}_{Pulse Air}$ (lb/min)	3.66		
	$P_{Sparger}$ (lb/in ² g)	2.5		
	Timer (on/off) (s)	0.3/2.6		
	Volume (Air) (sft ³ /min)	48.82		
	Material Rate (lb/h)	19,560		
	Transport Ratio (air) (lb/sft ³)	6.68		

Data Set: LS-5

	Gasifier	Regenerator	
<u>Bypass</u>			
ΔP_0 (in. H_2O)	83.19	76.70	
P_1 (lb/in ² a)	16.4	16.2	
T_1 (°R)	557	555	Notes
$P_{Fan Exit}$ (lb/in ² a)	17.5		*Assumed
$T_{Fan Exit}$ (°R)	561	554	†Sample average
μ (cp)	0.01864	0.01859	
η	0.95908	0.96193	
$\dot{Q}_{Bypass}$ (lb/s)	6.249	5.993	
$\dot{M}_{Bypass}$ (lb/h)	22,498	21,575	
<u>Beds</u>			
Amps	170	162	
$\dot{M}_{Total}$ (lb/h)	41,198	39,259	
$\dot{M}_{Fluidizing}$ (lb/h)	18,700	17,684	
T_{Plenum} (°R)	557	557	
P_{Plenum} (lb/in ² a)	16.7	16.7	
ρ_{Plenum} (lb/ft ³)	0.0810	0.0810	
V_{Plenum} (ft/s)	6.63	6.27	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0713	0.0713	
V_{Top} (ft/s)	7.53	7.12	
Display (start/end)			
Bed Wt. (start/end) (lb)			
Bed Ht. (start/end) (in.)			
ρ_{Bed} (start/end) (lb/ft ³)			
Θ_{Op} (s)	114		
<u>Spargers</u>			
T_{Tank} (°R)	530*		
P_{Tank} (start/end) (lb/in ² g)			
ΔP_{Tank} (lb/in ²)	5		
$\dot{M}_{Total Air}$ (lb)	5.55		
Air Rate (lb/min)	2.92		
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{M}_{Bleed Air}$ (lb/min)			
$\dot{M}_{Pulse Air}$ (lb/min)	2.92		
$P_{Sparger}$ (lb/in ² g)	2.5		
Timer (on/off)(s)	0.5/4.0		
Volume (Air) (sft ³ /min)	58.97		
Material Rate (lb/h)	16,060		
Transport Ratio (air)(lb/sft ³)	6.87		

Data Set: LS-5R

		Gasifier	Regenerator	
<u>Bypass</u>	ΔP_0 (in. H_2O)	82.6	76.7	
	P_1 (lb/in ² a)	16.4	16.2	
	T_1 (°R)	538	558	<u>Notes</u>
	$P_{Fan Exit}$ (lb/in ² a)	17.5		*Assumed
	$T_{Fan Exit}$ (°R)	563	557	†Sample average
	μ (cp)	0.01867	0.01867	
	γ	0.95937	0.96195	
	$\dot{Q}_{Bypass}$ (lb/s)	6.224	5.977	
	$\dot{Q}_{Bypass}$ (lb/h)	22,405	21,518	
<u>Beds</u>	Amps	170	160	
	$\dot{Q}_{Total}$ (lb/h)	40,962	38,552	
	$\dot{Q}_{Fluidizing}$ (lb/h)	18,557	17,034	
	T_{Plenum} (°R)	559	560	
	P_{Plenum} (lb/in ² a)	16.7*	16.7*	
	ρ_{Plenum} (lb/ft ³)	0.0807	0.0805	
	V_{Plenum} (ft/s)	6.60	6.07	
	P_{Top} (lb/in ² a)	14.7	14.7	
	ρ_{Top} (lb/ft ³)	0.0710	0.0709	
	V_{Top} (ft/s)	7.30	6.90	
	Display (start/end)			
	Bed Wt. (start/end) (lb)			
	Bed Ht. (start/end) (in.)			
	ρ_{Bed} (start/end) (lb/ft ³)			
	G_{Op} (s)	122		
<u>Spargers</u>	T_{Tank} (°R)	530		
	P_{Tank} (start/end) (lb/in ² g)			
	ΔP_{Tank} (lb/in ²)	5		
	$\dot{M}_{Total Air}$ (lb)	5.55		
	Air Rate (lb/min)	2.73		
	$\Delta P_{Annubar}$ (in. H_2O)			
	$T_{Annubar}$ (°R)			
	$P_{Annubar}$ (lb/in ² a)			
	$\rho_{Bleed Air}$ (lb/ft ³)			
	$\dot{M}_{Bleed Air}$ (lb/min)			
	$\dot{M}_{Pulse Air}$ (lb/min)	2.73		
	$P_{Sparger}$ (lb/in ² g)	2.5		
	Timer (on/off) (s)	0.5/4.0		
	Volume (Air) (scf ³ /min)	36.42		
	Material Rate [†] (lb/h)	15,760		
	Transport Ratio (air) (lb/scf ³)	7.21		

Data Set: LS-6

		Gasifier	Regenerator	
<u>Bypass</u>	ΔP_o (in. H_2O)	83.49	76.70	
	P_1 (lb/in ² a)	16.4	16.2	
	T_1 (*R)	557	557	<u>Note</u>
	$P_{Fan Exit}$ (lb/in ² a)	17.5		†Sample average
	$T_{Fan Exit}$ (*R)	563	556	
	μ (cp)	0.01864	0.01864	
	γ	0.95894	0.96195	
	$\dot{M}_{Bypass}$ (lb/s)	6.260	5.983	
	$\dot{M}_{Bypass}$ (lb/h)	22,535	21,537	
<u>Beds</u>	Amps	170	162	
	$\dot{M}_{Total}$ (lb/h)	41,198	39,259	
	$\dot{M}_{Fluidizing}$ (lb/h)	18,663	17,722	
	T_{Plenum} (*R)	558	559	
	P_{Plenum} (lb/in ² a)	16.6	16.6	
	ρ_{Plenum} (lb/ft ³)	0.0803	0.0802	
	V_{Plenum} (ft/s)	6.67	6.34	
	P_{Top} (lb/in ² a)	14.7	14.7	
	ρ_{Top} (lb/ft ³)	0.0711	0.0710	
	V_{Top} (ft/s)	7.53	7.16	
	Display (start/end)			
	Bed Wt. (start/end) (lb)			
	Bed Ht. (start/end) (in.)			
	C_{Bed} (start/end) (lb/ft ³)			
	ϕ_{Op} (s)	169		
<u>Spargers</u>	T_{Tank} (*R)	530		
	P_{Tank} (start/end) (lb/in ² g)			
	ΔP_{Tank} (lb/in ²)	5		
	$\dot{M}_{Total Air}$ (lb)	5.55		
	Air Rate (lb/min)	1.97		
	$\Delta P_{Annubar}$ (in. H_2O)			
	$T_{Annubar}$ (*R)			
	$P_{Annubar}$ (lb/in ² a)			
	$\rho_{Bleed Air}$ (lb/ft ³)			
	$\dot{M}_{Bleed Air}$ (lb/min)			
	$\dot{M}_{Pulse Air}$ (lb/min)	1.97		
	$P_{Sparger}$ (lb/in ² g)	2.5		
	Timer (on/off) (s)	0.3/7.0		
	Volume (Air) (scf ³ /min)	26.29		
	Material Rate (lb/h)	13,040		
	Transport Ratio (air) (lb/scf ³)	8.27		

Data Set: LS-7

	<u>Gasifier</u>	<u>Regenerator</u>
<u>Bypass</u>		
ΔP_o (in. H_2O)		
P_1 (lb/in ² a)		
T_1 (°R)		<u>Note</u>
$P_{Fan Exit}$ (lb/in ² a)		+Sample average
$T_{Fan Exit}$ (°R)		
μ (cp)		
γ		
$\dot{Q}_{Bypass}$ (lb/s)		
$\dot{Q}_{Bypass}$ (lb/h)		
<u>Beds</u>		
Amps		
$\dot{M}_{Total}$ (lb/h)		
$\dot{M}_{Fluidizing}$ (lb/h)		
T_{Plenum} (°R)		
P_{Plenum} (lb/in ² a)		
ρ_{Plenum} (lb/ft ³)		
V_{Plenum} (ft/s)		
P_{Top} (lb/in ² a)		
ρ_{Top} (lb/ft ³)		
V_{Top} (ft/s)		
Display (start/end)		
Bed Wt. (start/end) (lb)		
Bed Ht. (start/end) (in.)		
ρ_{Bed} (start/end) (lb/ft ³)		
ϕ_{Op} (s)		
<u>Spargers</u>		
T_{Tank} (°R)		
P_{Tank} (start/end) (lb/in ² g)		
ΔP_{Tank} (lb/in ²)		
$\Delta \dot{M}_{Total Air}$ (lb)		
Air Rate (lb/min)		
$\Delta P_{Annubar}$ (in. H_2O)		
$T_{Annubar}$ (°R)		
$P_{Annubar}$ (lb/in ² a)		
$\rho_{Bleed Air}$ (lb/ft ³)		
$\dot{M}_{Bleed Air}$ (lb/min)		
$\dot{M}_{Pulse Air}$ (lb/min)		
$P_{Sparger}$ (lb/in ² g)		
Timer (on/off) (s)		
Volume (Air) (ft ³ /min)		
Material Rate (lb/h)		
Transport Ratio (air) (lb/ft ³)		

Data Set: LS-8

	Gasifier	Regenerator	
<u>Bypass</u>			
ΔP_0 (in. H_2O)	82.90	76.70	
P_1 (lb/in ² a)	16.4	16.2	
T_1 (°R)	558	558	<u>Notes</u>
$P_{Fan Exit}$ (lb/in ² a)	17.5		*Assumed
$T_{Fan Exit}$ (°R)	564	558	†Sample average
μ (cp)	0.01867	0.01867	
γ	0.95925	0.96195	
$\dot{Q}_{Bypass}$ (lb/s)	6.234	5.977	
$\dot{Q}_{Bypass}$ (lb/h)	22,443	21,518	
<u>Beds</u>			
Amps	170	162	
$\dot{Q}_{Total}$ (lb/h)	41,198	39,239	
$\dot{Q}_{Fluidizing}$ (lb/h)	18,755	17,741	
T_{Plenum} (°R)	560	561	
P_{Plenum} (lb/in ² a)	16.6	16.6	
ρ_{Plenum} (lb/ft ³)	0.0800	0.0799	
V_{Plenum} (ft/s)	6.72	6.37	
P_{Top} (lb/in ² a)	14.7	14.7	
ρ_{Top} (lb/ft ³)	0.0709	0.0707	
V_{Top} (ft/s)	7.59	7.19	
Display (start/end)			
Bed Wt. (start/end) (lb)			
Bed Ht. (start/end) (in.)			
ρ_{Bed} (start/end) (lb/ft ³)			
ϕ_{Op} (s)	43		
<u>Spargers</u>			
T_{Tank} (°R)	530*		
P_{Tank} (start/end) (lb/in ² g)			
ΔP_{Tank} (lb/in ²)	5		
$\Delta \dot{H}_{Total Air}$ (lb)	5.35		
Air Rate (lb/min)	7.74		
$\Delta P_{Annubar}$ (in. H_2O)			
$T_{Annubar}$ (°R)			
$P_{Annubar}$ (lb/in ² a)			
$\rho_{Bleed Air}$ (lb/ft ³)			
$\dot{Q}_{Bleed Air}$ (lb/min)			
$\dot{Q}_{Pulse Air}$ (lb/min)	7.74		
$P_{Sparger}$ (lb/in ² g)	1.5 to 2.5		
Timer (on/off) (s)	Continuous		
Volume (Air) (aft ³ /min)	103.33		
Material Rate [†] (lb/h)	12,360		
Transport Ratio (air)(lb/aft ³)	1.99		